ESTIMATION OF SILVICULTURAL TREATMENT COSTS AND IDENTIFICATION OF MAJOR COST DETERMINANTS

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FINAL REPORT

Estimation of Silvicultural Treatment Costs and Identification of Major Cost Determinants

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ABSTRACT

SILVICULTURAL TREATMENT COST MODELS:
A METHODOLOGY FOR DEVELOPMENT

USDA Forest Service regulations addressing the mandates contained in the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) and the National Forest Management Act of 1976 (NFMA) require economic efficiency analysis for silvicultural activities on a site-specific basis. Recognizing that reliable financial and economic analyses must be supported by an accurate and representative data base, the regulations also call for the identification, and subsequent collection, of appropriately detailed information to "improve the accountability of agency expenditures" by expressing in qualitative and quantitative terms an "estimate of the sums necessary to replant and otherwise treat National Forest System lands."

The proposed methodology is designed to examine those qualitative and quantitative factors suspected of having an influence on several measures of cost and using those found to be significant to explain causal and predictive relationships. Multiple regression analysis is employed to develop models for the USDA Forest Service Region 6 in three general silvicultural activities; 1) site preparation, 2) reforestation, and 3) timber stand improvement. Cost is measured in terms of dollars and time on a per acre basis and for the total amount of each required to complete the operation. Silvicultural service contracts let by competitive bid during fiscal years 1976 and 1977 provided the observations for the dependent variables which include cost (the amount paid to the contractor),

man-hours, equipment hours, and days required to complete the job, USFS man-hours required for direct preparation, supervision, and inspection, and USFS cost for materials and/or equipment provided to the contractor. Site and stand characteristics, operational characteristics of the job, measures of accessibility, type of equipment used, and indicators of the contractor's level of experience and competence were included in the analysis as independent variables and found to influence costs in many models.

The exact methodology is presented to facilitate additional recommended analyses and the development of similar models for the remaining USFS regions. It is also essential to the support of conclusions and inferences made as a result of the study.

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CHAPTER I

INTRODUCTION

Statement of Problem

Cost effective production of timber in a manner consistent with other resource values is a major objective of forest management. Achievement of this objective requires a standardized and consistent approach to solving problems of choice.

Objectives must be defined with priorities assigned and the alternate means of accomplishing each must be identified. That alternative which yields the greatest return for a given cost or that alternative producing the desired level of benefits for the least cost may be selected to achieve the stated objective. Accurate estimation of all costs and returns generated by each alternative action is required to yield results which will point out and discourage investments leading to a misallocation or inefficient allocation of funds.

Silvicultural systems include all management actions employed to establish and/or manipulate vegetation. The selection, sequence, and timing of activities from initial site preparation and planting to final harvest constitute the major variables the resource manager can control in order to achieve a high level of cost effectiveness. In making decisions, the resource manager must consider each situation encountered as essentially unique due to the diversity of forest environments. Furthermore, more than one method may be feasible in completing a

desired objective depending on such parameters as timber type, condition of the site, and stand characteristics. The choice of components in the system and the methods selected to accomplish each component plays a major role in timber production decisions.

Allocations of management investments require an ability to determine priorities based on the ranking of costs and returns (physical and financial) from alternative management practices. Frequently, however, resource managers and planners are handicapped by the lack of relevant cost data applicable to most management practices. This is particularily true for timber management where costs vary according to site and stand characteristics. A site-specific procedure for estimating the cost of silvicultural operations is needed to aid the decision maker in selecting the most cost effective allocation.

Basic to the development of a reliable methodology is the availability and accuracy of site-specific data. Resource inventories frequently fail to record the value of many factors suspected of causing significant cost variations. Further, these inventories are generally not detailed enough to allow allocation of costs incurred by a specific project. Identification of influential factors and enactment of a more detailed accounting system will provide a more realistic definition of production costs. Consequently, budget proposals will more accurately represent the actual cost to be incurred and management objectives and alternatives can be selected by an objective procedure based on sound economic analysis.

There are several legislative mandates which call, directly or indirectly, for this type of analysis. The Forest and Rangeland Renewable

Resources Planning Act of 1974 (RPA) (4) calls for the Secretary of Agriculture to:

> "... develop and maintain on a continuing basis a comprehensive and appropriately detailed inventory of all National Forest System lands and natural resources."

which will include:

> "... estimates of investment costs and direct and indirect returns to the Federal Government."

and also allows:

> "... the identification of benefits associated with investments in such a manner that the anticipated costs can be directly compared with the total benefits and direct and indirect returns to the Federal Government."

The development of a procedure which will fulfill this charge will allow a:

> "... discussion of priorities for accomplishment of inventoried program opportunities, with specified costs, outputs, results, and benefits." (4)

Millions of dollars of federal and state funds are spent annually in the installation of silvicultural treatments and there is mounting pressure to allocate the investments on the basis of economic efficiency. Recent congressional legislation dictates some form of economic cost efficiency analysis to assist in selecting both levels of and alternatives to management activities.

The National Forest Management Act of 1976 (NFMA) (20) specifically designates $200,000,000 annually for the purpose of reforesting and treating lands in the National Forest System (NFS). Both RPA and NFMA require the Secretary of Agriculture to "improve the accountability of agency expenditures" (20) by preparing fiscal budget requests which express USDA Forest Service (USFS) activities in qualitative and

quantitative terms and include "estimate of sums necessary to be appropriated .... to replant and otherwise treat National Forest System lands" (20). Estimates should include:

> "... moneys needed to secure seed, grow seedlings, prepare sites, plant trees, thin, remove deleterious growth and underbrush, build fence to exclude livestock and adverse wildlife from regeneration areas and otherwise establish and improve growing forests to secure planned production of trees and other multiple use values." (20)

"The Secretary is further directed to specify guidelines for land management plans" (20) which:

> "... insure consideration of the economic and environmental aspects of various systems of renewable resource management, including the related systems of silviculture and protection of forest resources."

In addition, the planning process outlined in NFMA requires the identification of "lands within the management area which are not suited for timber production considering physical, economic, and other pertinent factors..." (20)

To facilitate this charge, the Secretary is also required to:

> "... formulate and implement, as soon as practicable, a process for estimating long term costs and returns ... including estimated expenditures associated with the reforestation, timber stand improvement, and sale of timber from the National Forst System ..."

It is admirable that Congress recognized the need for a more refined inventory record to support decisions based on sound economic analysis. However, the five years which have elapsed since the enactment of RPA have seen too little progress in these areas.

To assist land managers in their management planning efforts, the USFS has assembled a set of regulations which address the land use planning elements of NFMA. In summary, the regulations state that economic

efficiency analysis and justification will permeat the entire planning process. Alternatives will be formulated and those selected:

> "... will represent the most cost efficient combination of management practices examined that can meet the objectives established in the alternative." (21)

Net present value is the criterion to be used to achieve the efficiency evaluation requiring estimates of discounted costs and returns for each practice in the management prescription. Each proposed alternative will include an "estimate of real-dollar investments and operating costs." (21) An evaluation will follow the implementation of the selected alternative which:

> "... will contain for each monitored management activity at least a quantitative estimate of performance comparing outputs and services and their costs with those projected by the plan...." (21)

The ability to accurately estimate management practice costs for a specific site would contribute to the realization of cost-effective allocations. Production costs could be readily defined and program evaluations would report favorable correlations between actual costs incurred and budget proposals.

The regulations place additional emphasis on the development of appropriately defined criteria and a methodology to determine the "availability, capability, and suitability of lands for timber production." (21) Prior to the development of alternatives, the potential economic efficiency of commercial timber production on lands must be ascertained. An appropriate benefit-cost criterion is to be used to rank lands suitable for timber production. This assessment will "compare the anticipated direct benefits of growing and harvesting trees to the anticipated direct costs to the government." (21)

Economic efficiency standards need to be developed which will identify lands not suitable for timber production. A comparison of direct costs and benefits will allow an ordered ranking of lands in terms of their cost efficiency and expedite exposure of non-suitable lands.

Administrative regulation for delivery of the Forestry Incentives Program (FIP) (8) on non-industrial private lands also requires cost-effectiveness analysis of investments. The path taken to achieve this charge on FIP investments involves close program performance evaluation and development of maximum treatment cost guidelines derived at the national level and applied by the local manager. This would allow the identification of lower cost alternatives and help explain inter- and intra-state cost variations.

Recommendations made in RPA and NFMA and actions taken by the USFS in providing regulations concerning economic efficiency analysis and improved inventory data maintenance will contribute to developing cost effective timber production programs. However, an acceptable, standardized methodology which would allow the direct comparison of costs and returns associated with specific project proposals has yet to be developed. Without such an objective approach, alternative choices may result in an inefficient allocation of funds. Furthermore, public acceptance of proposed management plans may be impaired without economic justifications. Specific recommendations for improving inventory procedures are needed to support subsequent economic analyses. Most procedures currently employed fail to collect information vital to a reliable economic analysis leading to non-optimal resource decisions.

Objectives

Accurate estimation of costs and returns is essential to any realistic economic analysis intended to guide management decisions. Even

though management practice costs vary significantly from tract-to-tract, at present cost averages are frequently used in investment analysis leading to inaccurate investment decisions.

The primary objective of this study is to develop regional models for the NFS which relate silvicultural treatment costs to site-specific characteristics. Production costs can then be established for particular parcels of land allowing a comparison of direct costs and benefits. This will facilitate the selection of the most cost effective means of growing timber and possibly provide a criterion for establishing the suitability of land for timber production.

Specifically, models will be developed where warranted by sufficient amounts of information for five major practice categories within an administrative region of the NFS. Data will be collected for all regions for subsequent analysis if deemed appropriate. Major practice categories are defined as: 1) <u>Site Preparation</u> used to remove slash, small hardwood growth, and brush following final harvest of a merchantable stand in addition to scarifying the soil in preparation for direct seeding, planting, or natural regeneration; 2) <u>Reforestation</u> including direct seeding, planting by hand and/or machine, and natural regeneration; 3) <u>Timber Stand Improvement</u> (TSI) including control of understory vegetation, release of individual trees or areas by reducing competition from undesirable growth, precommercial thinnings, prunning, and fertilization; 4) <u>Protection</u> including fire prevention activities, slash disposal, and pest control; and 5) <u>Administration</u>, basically comprised of any inventory or stand exam activities. Within each practice, 6 cost type variables, representing the dependent variables, will be examined and models developed where appropriate. Cost is defined in units of

dollars and time as follows: 1) Total cost paid to the contractor and/or total cost/acre, 2) Man-hours (contractor) required to complete the operation, and/or man-hours per acre, 3) Equipment-hours required to complete the operation, and/or equipment-hours per acre, 4) USFS man-hours required for direct preparation, inspection, and supervision of the operation, and/or USFS man-hours per acre, 5) USFS cost for materials and/or equipment provided for the contractor, and/or USFS cost per acre, and 6) The total number of days required to complete the operation and/or days per acre.

Construction of the models yields a secondary benefit by identifying factors of production which exercise a significant influence on the cost of silvicultural operations. Consequently, a secondary objective is the recognition of these factors which should be included in future resource inventories to support more reliable economic analysis.

Scope

This effort will address national interests but will be carried out on a regional basis to allow for more accurate predictive capabilities. It will be directed at land management planning and program planning activities throughout the USFS with particular emphasis on the National Forests.

Data will be supplied for all NFS Regions in an attempt to represent all possible situations in the analysis. However, no single information system can provide the necessary inputs to relate costs to site-specific characteristics on a nationwide level. In this study USFS accounting records for silvicultural service contracts awarded and completed in fiscal years (FY) 1976 ('76) and 1977 ('77) will provide the cost, labor, and equipment requirement data for the study. Resource inventories for

the site coinciding with the area of operation will provide the information necessary to relate costs to site conditions.

CHAPTER II

DATA REQUIREMENTS AND COLLECTION PROCEDURES

General Considerations Concerning Data Collection and Analysis

Economic analyses are conducted to provide information to the decision making process which expedite and justify actions taken. They are also extremely valuable to the evaluation and interpretation of allocation model results. Economic models are developed not only to describe processes and support theories but also as a tool for prediction. Even though models are an abstraction or simplification of reality, they, like decision makers, require quantitative and qualitative information in order to approach a realistic solution.

As Morgenstern (12) points out, the most crucial problem in obtaining useful and reliable predictions lies in the accuracy of the data used to develop the models. The degree of accuracy necessary is largely determined by the purpose for which the model is to be used. Frequently, however, models are presented and used by decision makers which include no mention of their inherent accuracy or limitations. Decisions based on these incomplete accounts may prove disasterous if the decision maker places unwarranted confidence in a model for which the quality of the data was poor.

To avoid misuse of the models developed in this study and inform the user of their limitations, great care has been taken to present complete documentation concerning procedures used to collect the primary

data, assumptions made in developing the models, and recognition of major sources of error. Whenever possible, a quantitative estimate of each error's influence on the final figure will be made giving the user a basis for judging the value of the results.

Data Collection Procedures and Design

Several previous studies have produced evidence supporting the hypothesis that significant amounts of cost variation in silvicultural operations are accounted for by measurable factors which describe the characteristics of a particular site and stand (2, 5, 16, 17, 23). Each respective study however, was conducted for one region of the U.S., restricting the application of their results to the region from which the data originated. To address the legislative mandates cited in Chapter I, a nationwide approach is needed to provide a standardized methodology and data base that can be adopted uniformly by the entire NFS. This will facilitate interregional comparisons and is especially important to equitable budget allocations and as a criterion for determining the suitability of timber producing lands.

Due to differing economic conditions and physical feature diversity in the country as a whole, this preliminary investigation will subdivide data on the basis of USFS administrative region for each major practice occuring in that region (e.g. site preparation, reforestation, timber stand improvement, etc.). Models for each practice will include at least three equations designed to predict cost, man-hours, and equipment hours required for each major practice. Different stratifications may be possible and could involve further analysis, if warranted, by noting insignificant amounts of variation between regions and/or practices.

Tremendous amounts of accurate data are required to yield statistically significant results in a problem of this scale. Not only are the number of observations important, but the data must adequately represent all the possible situations (site/stand/practice combinations) that are likely to occur in a given region. Wikstrom and Alley (23) recognized that the key to an effective cost analysis was an information system which would: 1) provide accurate data on factors that affect both the costs and results of a treatment, 2) take into consideration the job circumstances and identify elements of the work plan that influence costs and results, and 3) provide cost data that can clearly be related to both resource and job factors. Unfortunately, as Hilliker, et al. (5) observed, there is no single information system which will supply the necessary inputs to relate costs to site-specific characteristics. However, the literature does suggest several sources and methods for computing relationships.

USFS silvicultural service contract reports were successfully used by Row (16) to develop cost prediciton models for the southern pine timber growing regions. He concluded that a substantial portion of per acre cost variations were due to factors such as the number of individual tracts treated, acreage, number of trees planted or treated, terrain characteristics, season of treatment, and forest type. Wikstrom and Alley (23) constructed total cost models using the USFS Northern Region's Forest Survey information. The inventory data provided valuable information on site and stand characteristics needed to develop models which were sensitive to such cost affecting elements as slope class,

soil type, and physiographic class. Both studies relied on regression analysis techniques which produced significant statistical results.

Since the cost of collecting new site-specific information for the entire NFS is prohibitive, this study will utilize both existing sources of data simultaneously. All USFS accounting records for silvicultural service contracts awarded and completed in FY's 1976 and 1977 (including the transition quarter of 1976) will be accessed. They will provide the actual cost figures, man-hours, and equipment hours required to complete the operation as well as an indication of the quality of the work completed and the competence and reliability of the contracted firm. These records are the most uniform source of cost data at the national level and represent every silvicultural practice currently employed in national forest management. Records including inspection reports are detailed enough to permit identification of projects and describe associated costs for each project. Furthermore, since contracts are let by competitive bid, they may approach a more accurate economic representation of the market price than might be the case with in-service treatment costs. The use of contracted operations is also becoming more widespread throughout the NFS which might support the notion of lower overall costs leading to greater efficiencies in resource deployment. This data source provides the dependent variables which will be related to site and stand information acquired from USFS Forest Survey records. Those measurements that coincide with the specific contracted site of operation were collected to describe the physical and biological characteristics.

Timber management directors from each USFS Region were consulted to determine which level in the NFS heirarchy was most appropriate for correlating contract reports to Forest Survey information. The district level was subsequently chosen since most prescriptions originate there and personnel are, in most cases, familiar with the particular job and the contractor. This relatively smaller area of concern also expedites the location of the appropriate Forest Survey information.

Both sources of information were collected via the use of a questionnaire (Appendix A). Prior to the construction of the questionnaire, a model must be hypothesized which attempts to account for the factors suspected of causing significant cost variations. Familiarity with contemporary forest management practices and experience in their implementation was extremely helpful in deciding which factors were important and should therefore be collected. Inputs from USFS timber management directors and conclusions drawn from previous studies also contributed to the construction of the questionnaire by suggesting important variables.

Since the main purpose of the model is prediction, it was desirable to limit the possible variables to measurable factors. Intuitively, however, one suspects that all the cost variation cannot be explained solely by site and/or stand characteristics. Consequently, some more or less subjective or qualitative variables were included to assist in the final evaluation of the project results. The qualitative information probably introduces a larger amount of error relative to most of the quantitative information acquired from hard copy data records. As a result, their influence and any inferences concerning them were weighted accordingly.

Many items are included in the questionnaire which require posteriori information (e.g., the number of bids received, total number of days on the job, weather conditions encountered, etc.). These factors were requested to account for further variation not represented by predictable or measurable factors and thus, provide a more complete accounting of all cost variation. They are also beneficial to the explanation of what will be referred to as causal relationships in the models. If these kinds of factors are found to exercise a significant influence on costs, future inventory efforts should strive to collect information which will allow their prediction or at least provide an indication of their magnitude. This posteriori information will also be helpful in explaining unusually high or low cost figures.

In formulating the questions, great care was taken to discourage ambiguity and allow for unique responses whenever possible. This effort may have been futile when considering the multiple area problem. Frequently the USFS requires the contractor to complete the same operation on a number of non-contiguous areas. Because each area is essentially unique with regard to its respective site and stand conditions, the application of a single set of data describing their characteristics would not be appropriate. Neither would it be feasible (as the pilot test demonstrated) to have the respondent complete one reporting form for each individual area. To obtain a representation for these areas, the respondent was instructed to categorize the individual areas on the basis of common bid values and/or plant community type. Data would then be reported for a single area in each category until each category was accounted for. Apparently, much confusion and anxiety resulted as evidenced by the 280 responses which were improperly

completed in terms of the multiple area question. Those forms that could not be rectified through personal communications with the respondent were removed from the analysis.

Prior to the distribution of the questionnaire, a pilot test was made using two arbitrarily selected national forests, the Medicine Bow in Wyoming and the Winema in Oregon. This resulted in the addition of one more item (total number of days on the job) and as previously noted, new instructions for dealing with multiple areas. The final forms were then distributed from the USFS's Washington Office to each region and then to the respective districts in each forest.

Logic Supporting Questionnaire Development

The questionnaire itself actually represents a hypothesis of the possible relationships thought to exist between the dependent cost variables and the individual elements of the specific operation. Proposed relationships were constructed by relying on previous cost study results, USFS timber management staff input, and the intuition gained through past experience. In an attempt to reduce the bias introduced by each source, information concerning every conceivable influential factor was collected so the analysis could proceed to thoroughly investigate the effect, if any, of many different elements and more fully satisfy the objectives of the study. Ideally, this approach would help eliminate the need to ask 'what if' type questions later since the method proposes to consider all possible factors. Unfortunately, this approach also requires a long and complex questionnaire which might warrant asking whether the quality of the data would be better if a shorter form were used? That is, shorter forms will normally receive more careful attention on the part of the respondent. Considering the

comments made in the next section, the answer is probably yes, but in any case, a thorough examination of all possible factors at this point is necessary to identify the significant factors to be included in future data collection procedures.

The following paragraphs describe each item included in the questionnaire, the reason, if not obvious, for its inclusion, the hypothesized effect on the dependent variables, and a subjective discussion on the reliability of the figure reported. Readers should note that these descriptions allow a clear explanation of the researchers intent in seeking the information. In the questionnaire this explanation was not given so as not to bias the respondent's reply. Since the information collected was to be analyzed using computer facilities, the reporting form attached to the questionnaire is laid out in a series of blocks summing to a total of four 80 column card images. Only numeric responses are appropriate for analysis so codes were provided to describe any qualitative information sought including an "other" specification, which when entered, was to be described on the back of the reporting form.

Items 1, 2, and 3 (Contract, Region, and Sample Number, respectively) together provided a unique number that identifies a particular contract. These items occupy the first 16 columns of every card so in the unfortunate event of a card shuffle, each piece will be returned to its proper place in the deck. The contract number is that assigned by the USFS office receiving the bids. When alphabetic characters were included in the designation they were numbered according to their position in the alphabet and substituted in the corresponding space(s). If the eight column field specification was exceeded, the left-most digits

were deleted. Item 3, Sample Number, was used to differentiate between multiple area contracts since they shared common contract and region numbers. This item was completed upon receipt of the questionnaire.

Numbers entered for Region, Forest, District, and State (Items 2, 4, 5, and 6 respectively) served to identify the origin of the contract and provide a basis for various area stratifications in the analysis.

The month and year the contract was awarded is recorded in Item 7. This information was collected primarily to verify that the award occurred within FY's 1976 and 1977. It was suspected that contracts awarded during the last quarter of the fiscal year tended to be more expensive and less productive than those awarded earlier. This could be due to an increased demand by the USFS for contracted work that needed to be implemented before the end of the fiscal year. In the analysis the month is recoded to indicate whether it is in the last or first three quarters of the year. The year awarded is used to approximate the inflation rate.

Respondents were instructed to use the most recent stand description inventory available to supply stand and site information corresponding to the contracted area. The month and year the inventory was preformed is recorded under Survey Date (Item 8). This information helps to verify whether the site and stand information recorded in subsequent sections of the questionnaire is an up-to-date representation of the field conditions encountered by the contractor.

Dollar amounts are recorded in Items 9, 9a, and 10. The bid of the successful contractor is entered under AWARD VALUE (Item 9) unless the contract was let on a hourly basis, in which case Item 9a (HOURLY RATE) is completed. Cost (Item 10) is the final total amount paid to

the contractor at the completion of the project. This data represents the set of observations for one of the dependent variables in the prediction equations. It is also considered as an independent variable for USFS manpower and cost projections. Major discrepancies between AWARD VALUE and COST were expected to occur when an inexperienced contractor received the award. The values recorded in Items 9, 9a and 10 are expected to be reliable since they are obtained from hard copy sources. However, as will be addressed in the next section, recording errors can occur either in the original contract document or when transferring the figure to the reporting form.

Up to this point, the information requested would be readily available, ordinarily, either as common knowledge or from a cursory review of the written contract. Completing the remainder of the questionnaire requires a more indepth inspection of the contract and any supporting information such as the stand description inventory and/or the cost estimate appraisal prepared by the contracting officer.

Item 11, the total number of bids received for the contract, is not always included in the supporting documents that accompany the actual contract. Normally, a complete list of contractor names, addresses, and amount bid is maintained for each advertised contract to provide a history of bids. A large number of bids may indicate greater competition which might reduce the award value. This information is not useful to cost prediction as it is not known until after the fact. If found to have a negative correlation with cost as is suspected, it would be a worthwhile objective to collect as many bids as possible before awarding a contract.

Contractor Status (Items 12a, b, c, and d) represents an attempt to establish the reliability, competence, and experience of the contractor by measuring the number of individual pieces of equipment owned (Item 12 a), the number of persons employed (Item 12 b), the percentage of time the contractor spends performing silvicultural operations (Item 12 c), and the number of years the contractor has been in the business (Item 12 d). Each of these figures reported is most often an estimate on the part of the respondent. In many cases no information is provided because the respondent was new to the area and/ or not personally involved in the project. The actual wording in the questionnaire was also found to be somewhat ambiguous since "pieces of equipment" could include everything from hand tools to helicopters and "total number of employees" could include temporary as well as permanent employees. This information is of little value for predictive purposes but if a positive correlation exists between limited experience and defaults then this kind of information could be useful in evaluating the probability of contractor success.

Job Performance (Item 13a and b) records the quality and success of the completed operation. Codes are provided so the respondent can evaluate the degree to which the terms of the contract were met (Item 13a) and the quality (Item 13b) of the work actually completed. This information was extremely subjective, but the objective was to avoid considering contracts resulting in defaults or unacceptable work progress. Only those contracts which yielded acceptable quality work were considered in the analysis.

Items 14 and 15 record the dates (month and year) actual field work began and ended, respectively. These items were used to verify that

contracts were awarded and operations completed within FY's 1976 and 1977 as specified in the instructions. Daily USFS inspection reports attached to the contract include the information necessary to complete these items.

Labor and equipment required to complete the job are included in Items 16 through Item 19. Information reported here is essential to the analysis and can only be ascertained by careful inspection of the daily reports. Respondents were asked to record the total number of non-USFS personnel directly involved in the field operations under Labor (Item 16). This information should be fairly reliable as it is recorded in the inspection reports. It is suspected of being an important factor for predicting all dependent variables. If a negative correlation is found to exist between this variable and the cost variables, it may be a viable criterion for choosing between contractors with different numbers of employees. Total number of man-hours required to complete the job is recorded under Man-hours (Item 17) and represents the observations for one dependent variable as well as observations as an independent variable in the other models. Unfortunately, it is an estimate derived by the respondent using the total number of days actually spent working and the information in Item 16 (Labor). Its reliability is certainly questionable as the estimate is a function of the deligence expended by the respondent, his knowledge of the operation, and/or the quality of the daily reports. Equipment Hours (Item 19) suffers from the same limitations with respect to its estimation. This item also serves as one dependent variable and is included as an independent variable in the remaining models. A high positive correlation is expected to exist between equipment hours and man-hours

for capital intensive operations and may eliminate the need for separate models in such cases. Up to five codes, representing the type of equipment used ranging from non-powered hand tools to helicopters, can be recorded under Equipment (Item 18). For a particular job, certain types of equipment were expected to be more efficient than others with respect to time and/or money.

Data representing USFS contributions and inputs to the operation is reported in Item 20 thru Item 23. An estimate of the total number of USFS man-hours spent on direct preparation, inspection, and supervision of the job is entered under FS Man-hours (Item 20). The accurcy of this value is also a concern because of the subjective nature of the calculation. Nevertheless it will be considered as one dependent variable and as an independent variable in the remaining models. Costs incurred by the USFS for materials and/or equipment provided for the contractor are recorded in Item 22. This value will also comprise the dependent variable in one of the models. It is considered to be fairly reliable since monies spent on operations are carefully documented. Frequently, however respondents included USFS wages for personnel involved in inspection, supervision, and preparation. When these wages were suspected of being included in the values, the figures were deleted from consideration. The average civil service grade level of USFS personnel directly involved in the field operations is reported under Item 21 (FS Grade). Material and/or equipment provided by the USFS for the contractor is recorded in Item 23 (FS Material) and should be reflected by Item 22, the cost incurred by the USFS. Up to seven codes could be entered with the left-most representing the most costly item.

Using codes to adequately describe the precise nature of the work done was a difficult task. A total of 124 codes were provided to be entered in two blocks, Items 24a and 24b. Respondents were allowed to enter codes specifying "other" in the event the list failed to include a description that fit the contract specifications. The two blocks are identical in format and are provided so the respondent could report contracts requiring two distinct jobs such as site preparation followed by planting. Each block has one field labeled Practice which describes the general category of the job (e.g., site preparation, reforestation, TSI, etc.). The second field, labeled Activity, is a more specific delineation within the general practice category. Up to two specific methods employed to complete the practice can be recorded in two additional fields within each block. An example of the correct procedure for completing these blocks is included in the questionnaire. The practice recorded provides another basis for stratification within each region. Where several feasible alternative methods are available within a particular practice, it is possible that one method may be more efficient than another.

Multiple areas are dealt with under Items 25a, b, and c. As mentioned earlier, the USFS frequently lets contracts which cover several non-contiguous areas in an effort to reduce paperwork and consequently, USFS costs. According to the instructions, respondents were required to categorize the areas on the basis of common bid values and similar site and stand characteristics. All the information entered on the reporting form was to apply specifically to the one area within a category chosen as a representative of that category. Additional forms were to be completed until each category was accounted for. Item 25a (Number)

records the number of areas within a category represented by the area being reported. To verify that instructions were being followed and the forms were being completed correctly, the total number of different bid values accepted for the different areas was to be entered in Item 25b (Bid Values). Assuming the instructions were interpreted correctly, if a number other than 0 appeared in Item 25b, then the response should have included at least that number of reporting forms all having identical contract numbers. Intuition suggested that if the contractor felt compelled to bid a higher value for one or more areas than the others, then there must be some peculiar physical characteristic(s) which the contractor felt would make the task more difficult relative to the other areas. The average distance (miles) between the areas represented on the reporting form is recorded in Item 25c (Distance). The magnitude of this item was expected to effect the time required to complete the operation due to traveling time incurred from area to area.

Total acreage covered by the contract, or in the case of multiple areas, the representative area, is recorded in Item 26 (Acres). A high positive correlation is expected to exist between all of the dependent variables and acreage. In this study it is also necessary to derive per acre figures as a means of standardization to allow comparisons between various stratifications to be investigated.

Travel time from the contractor's base of operations to the actual work site was expected to contribute to the cost and/or man-hour requirements. Items 27a, b, and c record the distance in minutes, miles, and miles from all weather roads, respectively. These items were included to give some indication of the ease or difficulty of accessibility to the work site. These items are average estimates but should be

fairly accurate if the respondent is at all familiar with the area.

Codes were provided to identify the season(s) (Item 28) in which the majority of the field work was completed. Row (16), in a similar study, suggested that this factor be investigated. It is of particular significance in areas of the country where there are dramatic differences in weather conditions during the year.

Items 29a, b, and c (Planting) pertain only to reforestation contracts. Total number of seedlings planted per acre are recorded under Item 29a (Seedlings) as this value was expected to have a direct effect on cost and man-hours. Elapsed time (months) since site preparation was completed was also expected to have a significant effect and is recorded in Item 29b (Months). The species planted (Item 29c) is also recorded. No codes were provided for this item so respondents were asked to cite the species on the back of the reporting form. After receipt of all forms, codes were designated and entered on the forms.

Man-hour requirements for some TSI operations were suspected of being sensitive to whether or not stems to be treated were marked prior to the labor force's arrival. To indicate which situation occurred, the respondent was asked to record a "1" in Item 30 (Marked) if items had, in fact, been marked for treatment, otherwise, a "0" was to be entered.

Many jobs contain as a standard amendment, a provision requiring fire line construction around the work site and piling of slash. Item 31a records the total fire line footage constructed and Item 31b has a "1" entered if piling of slash was required, otherwise, a "0" is

recorded. Either requirement was expected to impact cost, man-hours, and/or equipment-hours.

Severe slopes have been found to have a significant effect on cost, man-hours and/or equipment-hours (2) (16). Codes describing four degree classes of slope from level to steep were provided to be entered in Item 32 (Slope). This entry represents the average condition on the majority of the work sites. Its reliability is a question of the respondents knowledge of the area but the information is recorded in the stand exam. Since the extreme case is what's expected to be influential, it is assumed the respondent can ascertain whether or not the area is steep.

Elevation (feet above sea level) is recorded in Item 33 for the average condition existing over the majority of the work site. High elevations are suspected of slowing work progress because of the unusually severe weather conditions which frequently persist affecting both man and/or equipment hours spent completing the job.

Physical features of the work site which cannot be quantified but are suspected of impeding the progress of man power and/or machinery are represented by the 14 codes listed under Item 34a (Operability) in the questionnaire. Respondents were allowed to enter up to two codes describing the most severe and potentially costly obstacle occurring on the work site. The percentage of the total work area affected by the obstacle recorded was entered in Item 34b (Percentage). A rating was entered from codes in the questionnaire in Item 34c (Rating) describing the effect, if any, on equipment chosen and/or the degree to which progress was impaired.

Forest type delineations taken from the USFS Handbook ( ) are presented in Item 35 in the questionnaire. Respondents were required to enter the code appropriate for the area prior to treatment. Forest type itself represents a number of physical and biological features of the site so it alone may be found to be more important than the individual measures of site characteristics. For example, Row (16) found it to be an appropriate criterion for primary stratification prior to his analysis.

Stand characteristics are recorded in Item 36 through Item 40. Several previous studies have found these factors to be significant (5) (16) (23). In fact, the delineation for ground cover under Item 40 (Vegetative Cover) was taken from the Hilliher et. al. (5) study. This information was expected to be most appropriate in the examination of TSI treatments but is also applicable to some site preparation jobs. Basal area per acre before treatment and treated are recorded in Items 36 and 37, respectively. Total number of stems treated and their average DBH is recorded in Items 38 and 39, respectively. Up to three codes could be entered under Item 40 to describe the size, amount, and type of ground cover occurring over the area. Since this information is not recorded in any known inventory, its reliability is purely a function of the respondents knowledge of the area.

As stated earlier, Item 41, total number of days on the job, was added as a result of the pilot test. Originally, the beginning and ending dates of field work (Items 14 and 15, respectively) were expected to provide this information. However, inclement weather, holidays, and any number of other problems would frequently stop work on a project for as much as several months. Therefore this item was added to record

the number of days actually worked. An inspection of the daily reports should provide a reasonable estimate of this value.

Item 42 (Remarks) was also added to encourage respondents to identify any peculiar factors which may have contributed to unusually high or low contract award values. Remarks that were provided, frequently resulted in the elimination of the contract from consideration because the operational characteristics of the job were either too specialized or the circumstances too unique for the purposes of this study.

Analyses described in the remainder of this paper will attempt to examine the effect of each item collected in the questionnaire. All the items, except those used for identification, are suspected of having some influence on one or more of the dependent cost variables. The magnitude of that influence and consequently, the importance of those factors in a causal and predictive sense will be revealed in the analyses that follow.

Comments Concerning Errors

During the model development stages and evaluation and interpretataion of results one must "recognize the fundamental importance of errors, together with the unpleasant fact that they cannot be made 'as small as desired' and must be included in the theory" (12). Recognition of the possible sources and their impact will contribute to the minimization of large accumulations which render the results useless.

The opportunity for errors occurring permeates every phase of this study. Field measurements taken for the Forest Survey have associated errors due, at least, to instrument limitations and the competence of the user. These measurements as well as the cost

data may be recorded erroneously and of course, the same might occur while completing the reporting form for this study. The proposed model itself probably contains errors by failing to represent the true functional form or excluding variables which should have been considered. Some bias is certainly introduced simply in the manner in which questions are worded on the questionnaire. The respondent may "read between the lines" and attempt to supply information he thinks the researcher wants to see.

Tremendous room for error exists in completing the questionnaire because of its length and complexity. The respondent who completes more than ten questionnaires (which is frequently the case) will probably be more careful in completing the first than he is the last. It's possible that some respondents completed the forms with the aid of a "random number generator" to finish the task quickly. Others may have done the same thing to hide the fact that the information was just not available, i.e., the on-site information system was too poor to make the necessary correlations. Mistakes were frequently made because the respondent recorded a unit of measure familiar to him but different from that sought in the questionnaire. This kind of error occurrence could be reduced by carefully reading the question; approximately 350 respondents apparently failed to read (or understand) the first instruction on the questionnaire at all since they reported contracts awarded some time other than FY 1976 or 1977!

The preceding paragraphs are by no means a complete enumeration of all the possible areas of error introduction. They do, however, illustrate the wide range of possibilities. From the beginning of this investigation, recognition was given to the fact that the major source of

error would involve the completion of the reporting forms. In order to reduce the possibility of carrying these errors over into subsequent steps in the analysis, several examinations of each form were made to identify inconsistencies and rectify, or eliminate from consideration, suspected errors. Forms were removed from the sample if they violated the instructions, reported defaulted contracts, or recorded insufficient amounts of information (e.g., no acreage, cost, or practice data).

Each item in the questionnaire was checked to verify the satisfactory following of instructions such as Contract Date, Multiple Area, Bid Values, and the dates when work began and ended. Since the beginning and ending dates of actual field work are recorded in the daily inspection reports and, consequently, considered fairly reliable, the time span between the two was used to determine whether the estimates of days on the job, USFS man-hours, man-hours, and equipment hours recorded were reasonable in that (the calculated) amount of time. Any values failing this or any other tests were removed from consideration. USFS cost was examined to make certain the reported value did not include USFS personnel wages. The value reported for USFS man-hours and the code(s) recorded for USFS provided equipment and/or materials were used to screen these values.

Given the practice code(s) recorded, all missing information on the reporting form was coded to indicate whether the particular item was applicable to the job and no information was provided, or the item was not applicable and left blank. Under no circumstances, was information supplied through deduction or inference for a blank item. All coded information was also checked to verify that it fell within a range appropriate for the job described. The explanation for each

"other" specification entered on the form was itemized and assigned a code which was later entered on the form in place of the code signifying "other." Any excessively large or small entries were evaluated after the distributional characteristics of each variable were determined (Chapter 3).

It snould be noted here that even though tremendous effort was expended on editing and screening of the primary data, errors continued to be discovered during the analysis. Those discovered were subsequently eliminated but their presence during a major portion of the analysis reduced the significance and/or validity of many preliminary findings. Most of the results presented in this document are based on what is believed to be a "clear" data base but because of the oversights in the preliminary data examination, acquisition of those results required considerable accumulations of additional time and monies.

Another important source of error is possible during the transfer of data from the reporting form to the computer input medium. To avoid these, each line of information entered was verified by the keypuncher before preceding to the next line. After all the data was filed, a computer program was written to check each record for column shifts and completeness of entries. Any errors detected were corrected before continuing to the next step in the analysis.

The user of economic models must be aware of the details of composition, stages of classification, and all other characteristics of the statistics to objectively evaluate the information gained from such models. The accuracy of the data employed for the model formulation defines the maximum capabilities of that model. Decisions based on information obtained from the model should carefully consider the possible errors included and the limitations of application.

This chapter has attempted to present a detailed description of the forethought, design and procedures used in collecting the necessary data for this study. Efforts will be made in subsequent chapers to be as thorough so the confidence placed in the final results can be justified and supported with complete documentation.

CHAPTER III

METHODOLOGY

All data analyses were accomplished using the procedures and capabilities of the Statistical Package for the Social Sciences (SPSS). SPSS offers a wide variety of computer programs which include a comprehensive set of procedures for data transformation and file manipulation, and a large number of commonly used statistical routines. Data-management capabilities of the package are especially attractive for the purposes of this study as they will allow the various stratifications of the data and easily accommodate the large variable list resulting from data transformations.

After editing and screening procedures outlined in Chapter II were completed the raw data was used as input for the initial SPSS program. The run established a permanent working file which was accessed on all subsequent analyses. The file created by this run has four features in particular that are worth noting; 1) each item included in the raw data is defined with a variable name, 2) missing value indicators are acknowledged for each variable and retained, 3) labels, as specified by the user, are attached to all coded values for easy reference, and 4) data transformations specified are calculated and retained for future use.

Data transformations and recoding of discrete variables yielded a total of 611 variables in the file. Actual data transformations, i.e., the calculation of per acre values for the dependent variables and the

computation of acres squared, the recipical of acres and acres squared only added nine new variables. The remaining new variables came about because of the recoding necessary to represent the qualitative (discrete) variables in the original raw data set. Because the codes supplied in the questionnaire are for identification purposes only, their value does not correctly reflect the contribution of that variable on the dependent variable in regression analysis. In order to investigate the effect of a discrete variable, such as type of equipment used, it is necessary to set up "dummy" variables that represent the probable range of variation in that variable (23). All of the categorical variables in the questionnaire may be interpreted on a present or absent basis; for example, a helicopter was the principle type of equipment used or it wasn't. Each category or code, therefore, can take on only one of two values; a "1", indicating its presence, or a "0", indicating its absence. Virtually every code in the questionnaire becomes (or can be considered) a separate and unique variable that can take on only one of two values. The "list" of new variables is further compounded by each item in the questionnaire that allows multiple entries. For example, consider Item 34a, Obstacle; 13 codes are presented in the questionnaire, each of which becomes a separate variable according to the previous discussion. Since two entries are allowed, another 13 new variables must be created to account for the second entry. Up to seven separate entries are allowed under Item 23, material and/or equipment provided by the USFS. Eight codes are presented in the questionnaire, so upon creation of the dummies, 56 new variables result. Fortunately, relatively few of the dummy variables are entered

in any single regression run, but over 500 "dummies" were created and stored in the SPSS permanent file. Table 1 in the Appendix with the questionnaire describes the dummy variables appropriate for the analysis as well as the new variable designation numbers resulting from coding required for computer input. With the information presented in these paragraphs in mind, the discussion of the steps in the analysis follows.

In order to establish regional subfiles, the number of cases in each region must be determined. SPSS subroutine FREQUENCIES was used here. Its primary function is to count the occurrence of specified variables or codes (this subroutine was employed extensively throughout the investigation to obtain distributional characteristics for variables of interest). Permanent subfiles were created using the SPSS SORT routine which grouped cases in a heirarchy according to USFS Region (Item 2), Practice (Item 24a), Forest (Item 4), and District (Item 5).

Results of two frequency runs are presented in Table 2 showing the number of observations (cases) in each practice category and the totals for each region. Those categories within any region having at least 15 cases are possible candidates for additional analysis, however, a minimum of 30 observations is the accepted standard for most statistical analyses. Inferences made concerning models utilizing less than 30 observations may be subject to question concerning their statistical significance.

Since the primary objective of this paper is to present the logic and procedures appropriate for developing prediction equations. One

Table 2. Total number of observations (cases) within each USFS Region for major silvicultural practice categories.

USFS Region Number	Site Preparation	Reforestation	TSI	Protection	Administration	Total
1	58	23	62	4	0	147
2	1	8	40	0	5	54
3	18	52	127	7	0	204
4	41	34	23	9	0	107
5	84	59	134	19	1	297
6	117	253	217	40	25	652
8	125	69	25	0	5	224
9	103	73	48	0	1	225
10	0	0	3	3	0	6
Total	547	571	680	82	37	1916

USFS region was selected to illustrate the application of the approach. Region 6 was selected since it has the greatest number of observations in each of the treatment categories.

Basic Analysis Procedure

As stated previously, the primary objective of this study is to develop models capable of reliably predicting costs for silvicultural activities under a wide variety of circumstances. Theoretically, the term "mathematical model" normally suggests a causal relationship developed using sample data from which inferences about the relationships in the population as a whole can be made. Prediction, on the other hand, is primarily concerned with the evaluation and measurement of the overall dependence of one variable on a set of other variables that are not necessarily constructed or supported by causal theory. This distinction introduces the possibility of three different approaches to model formulation; 1) the hypothetical approach, in which a logical model is proposed and the data is tested to determine whether or not the sample supports the hypothesis, 2) the descriptive approach, which seeks the "best" linear prediction equation and evaluates it predictive accuracy or, 3) a combination of the two which attempts to represent all (the) possible linkages between dependent and independent variables and to "assess the logical consequences of a structural model that is posited a priori from some causal theory" (13). The analysis that follows proposes to start with the hypothetical approach and iteratively, move to the descriptive approach resulting in a model that can be used for predictions. Variables identified as being influential factors will be recognized regardless of whether they appear in the final models or not.

Tables 3 through 18 summarize the hypothesized models. Measurement levels (continuous or discrete) are indicated as well as the significance, if any, supported by subsequent analyses. Information that is available prior to completion of the operation (a priori) and is thus useful in a predictive sense is noted. Also noted is that information which is suspected of exercising a significant influence on the cost variable but is not available until after the completion of the operation (posteriori). Although this information is not useful for prediction, it is appropriate to a discussion of causal relationships.

Regardless of the approach chosen, multiple regression analysis is an appropriate tool for expressing and measuring the relationships between costs and a set of independent variables. Statistics produced by the procedure are appropriate for making objective comparisons between various models; however, some judgement is frequently necessary to make a final selection. The procedure is similar to analysis of variance in its ability to test variables while controlling for the confounding effects of other factors. This feature is extremely important in light of the large number of variables considered in this study.

<u>Primary Data Analysis</u>

Initially, the data for Region 6 was stratified by major practice. Distributional characteristics of all variables within each stratification were obtained using SPSS subroutine FREQUENCIES. This procedure not only provides the distribution, variability, and central tendencies of each variable but is also extremely valuable to the identification of erroneous data. All entries in the file are itemized with the corresponding frequency of response so coding errors may be ascertained simply

by inspection. The number of observations reported for each code is also useful to the definition of appropriate dummy variable lists since those codes or variables having less than 1 percent of the total number of observations can be dropped from subsequent investigations. One percent was used as this usually eliminated those variables with three or less observations which contribute little, if any, information to the analysis. The "method(s)" to be included in the analysis were identified in this fashion. For example, of the 13 methods reported for completing site preparation, 8 were finally included in the analysis. Precommercial thinning using power saws was the only method analyzed for TSI operations, as the number of observations in any other single method was too small for analysis. Table 19 summarizes the methods included for site preparation and reforestation. Variables considered limiting because of the large number of missing values, were also identified from the FREQUENCIES output (Tables 3 through 18).

Basically, multiple regression attempts to produce a linear combination of independent variables which will correlate as highly as possible with the dependent variable. The function derived may thus be used to "predict" values of the dependent variable but only within the range of variance included in the sample used to develop the model (3). Also, the closer the values of the independent variables approach the mean conditions of the sample, the more accurate will be the estimate provided by the equation (23). In fact, prediction should not be attempted if the values for a situation for which an estimate is desired fall outside the range of observations used to develop the models. Therefore, the mean and standard deviation of each variable included in the

Table 3. Methods considered in the analysis which were site preparation and reforestation operations.

Site Preparation:

- Tractor and Scalper
- Strip with tractor and blade
- Complete with bulldozer and blade
- Bulldozer and discs
- Whip felling
- Scarification
- Windrowing
- Helicopter with chemical spray

Reforestation (planting):

- Machine
- Hand
- Auger
- Auger and hand

Table 4. Hypothesized Model for Cost and Cost per Acre Required for Completion of Site Preparation Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 13	N	D	P	
14	N	D	P	
Item 19	N	C	P	
20	N	C	P	
21	N	C	P	
22	N	C	P	
23	S	C	P	
DEGREE	N	D	P	
QUAL	S	D	P	
Item 40	S	C	A	
46	N	C	A	
EQUIP	S	D	A	
MET	S	D	A	
Item 74	N	C	A	
76	N	C	A	
77	S	C	A	
78	N	C	A	
79	N	C	A	
80	S	C	A	
SEA	S	D	A	
Item 89	N	C	A	L
90	S	D	A	L
SLOP	S	D	A	
Item 92	S	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
Item 107	S	C	A	L
108	N	C	P	L
109	S	C	A	L
110	N	C	A	L
VEG	S	D	A	
ACSQU	S	C	A	
ARECIP	S	C	A	
A2RECIP	N	C	A	

1/ Dependent variables examined. See questionnaire for explanation of variable name.

2/ Indicates which variables were found to be significant (S) (at 5percent probability) during any single phase of the analysis including scattergram, correlation, and regression analyses. Those factors whose significance was never established are also indicated (N). Dummy variable lists represented by their mnemonic variable name are indicated as significant if any single variable was found influential.

3/ Designates variables treated as continuous (C) or as discrete (D), usually including dummy variables.

4/ Denotes variables available or capable of being estimated, a priori (A) as opposed to those factors measuring posteriori (P) information.

5/ Identifies variables having a large number of missing values thereby limiting the number of observations in the data base.

Table 5. Hypothesized Model for Man-Hours and Man-hours per Acre Required to Complete Site Preparation Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 20	N	C	P	
21	N	C	P	
22	N	C	P	
23	N	C	P	
DEGREE	N	D	P	
QUAL	N	D	P	
Item 46	S	C	A	
EQUIP	S	D	A	
MET	S	D	A	
Item 74	N	C	A	
76	N	C	A	
77	S	C	A	
78	S	C	A	
79	S	C	A	
80	S	C	A	
SEA	S	D	A	
Item 89	N	C	A	L
90	N	D	A	L
SLOP	S	D	A	
Item 92	N	C	A	
OBS	S	D	A	
FTYPE	N	D	A	
Item 107	N	C	A	L
108	N	C	P	L
109	N	C	A	L
110	N	C	A	L
VEG	S	D	A	
ACSQU	S	C	A	
ARECIP	N	C	A	
A2RECIP	N	C	A	

Table 6. Hypothesized Models for Equipment Hours and Equipment Hours per Acre Required to Complete Site Preparation Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 20	N	C	P	
21	S	C	P	
22	N	C	P	
23	N	C	P	
DEGREE	N	D	P	
QUAL	N	D	P	
Item 40	S	C	A	
EQUIP	S	D	A	
MET	S	D	A	
Item 74	N	C	A	
76	N	C	A	
77	S	C	A	
78	N	C	A	
79	N	C	A	
80	N	C	A	
SEA	S	D	A	
Item 89	N	C	A	L
90	N	D	A	L
SLOP	S	D	A	
Item 92	S	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
Item 107	N	C	A	L
108	N	C	P	L
109	N	C	A	L
110	N	C	A	L
VEG	S	D	A	
ACSQU	N	C	A	
ARECIP	N	C	A	
A2RECIP	N	C	A	

Table 7. Hypothesized Model for USFS Man-Hours and USFS Man-hours per Acre Required to Complete Site Preparation Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 18	S	C	A	
Item 19	N	C	P	
20	S	C	P	
21	S	C	P	
22	N	C	P	
23	S	C	P	
DEGREE	N	D	P	
QUAL	N	D	P	
Item 40	S	C	A	
46	S	C	A	
EQUIP	S	D	A	
MET	S	D	A	
Item 74	S	C	A	
76	S	C	A	
77	S	C	A	
78	S	C	A	
79	N	C	A	
80	S	C	A	
SEA	S	D	A	
Item 89	N	C	A	L
90	S	D	A	L
SLOP	N	D	A	
Item 92	S	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
VEG	S	D	A	
Item 107	N	C	A	L
108	N	C	P	L
109	N	C	A	L
110	N	C	A	L
ACSQU	S	C	A	
ARECIP	S	C	A	
A2RECIP	N	C	A	

Table 8. Hypothesized Model for Days and Days per Acre Required to Complete Site Preparation Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 18	N	C	A	
20	N	C	P	
21	S	C	P	
22	N	C	P	
23	S	C	P	
DEGREE	S	D	P	
QUAL	S	D	P	
Item 40	S	C	A	
46	S	C	A	
EQUIP	S	D	A	
MET	S	D	A	
Item 74	S	C	A	
76	N	C	A	
77	N	C	A	
78	N	C	A	
79	N	C	A	
80	N	C	A	
SEA	S	D	A	
Item 89	N	C	A	
90	N	D	A	
SLOP	S	D	A	
Item 92	N	C	A	
OBS	N	D	A	
FTYPE	N	D	A	
Item 107	N	C	A	L
108	N	C	A	L
109	N	C	A	L
110	N	C	A	L
VEG	S	D	A	
ACSQU	N	C	A	
ARECIP	N	C	A	
A2RECIP	N	C	A	

Table 9. Hypothesized Model for Cost and Cost per Acre Required for Completion of Reforestation (Planting) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 13	S	D	P	
14	S	D	P	
Item 19	S	C	P	L
20	S	C	P	L
21	N	C	P	L
22	S	C	P	L
23	S	C	P	L
DEGREE	S	D	P	
QUAL	S	D	P	
Item 40	S	C	A	
46	S	C	A	
EQUIP	S	D	A	
MET	S	D	A	
Item 74	S	C	A	
76	S	C	A	
78	S	C	A	
79	N	C	A	
80	S	C	A	
SEA	S	D	A	
Item 85	S	C	A	
86	N	C	A	L
SPEC	S	D	A	
SLOP	S	D	A	
Item 92	N	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
VEG	S	D	A	L
ACSQU	S	C	A	
ARECIP	N	C	A	
A2RECIP	N	C	A	

Table 10. Hypothesized Model for Man-Hours and Man-Hours per Acre Required to Complete Reforestation (Planting) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 20	S	C	P	L
21	S	C	P	L
22	S	C	P	L
23	S	C	P	L
DEGREE	S	D	P	
QUAL	N	D	P	
EQUIP	S	D	A	
Item 46	S	C	A	
MET	S	D	A	
Item 74	S	C	A	
76	S	C	A	
77	S	C	A	
78	S	C	A	
79	S	C	A	
80	S	C	A	
SEA	S	D	A	
Item 85	S	C	A	
86	S	C	A	L
SPEC	S	D	A	
SLOP	S	D	A	
Item 92	N	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
VEG	S	D	A	L
ACSQU	S	C	A	
ARECIP	S	C	A	
A2RECIP	S	C	A	

Table 11. Hypothesized Model for Equipment Hours and Equipment Hours per Acre Required to Complete Reforestation (Planting) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 20	S	C	P	L
21	S	C	P	L
22	S	C	P	L
23	S	C	P	L
DEGREE	S	D	P	
QUAL	N	D	P	
EQUIP	S	D	A	
Item 40	S	C	A	
MET	S	D	A	
Item 74	S	C	A	
76	S	C	A	
77	S	C	A	
78	S	C	A	
79	S	C	A	
80	S	C	A	
SEA	S	D	A	
Item 85	S	C	A	
86	S	C	A	L
SPEC	S	D	A	
SLOP	S	D	A	
Item 92	S	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
VEG	S	D	A	L
ACSQU	S	C	A	
ARECIP	S	C	A	

Table 12. Hypothesized Model for USFS Man-Hours and USFS Man-Hours per Acre Required to Complete Reforestation (Planting) Operations.

FACTORS 1/	SIGNIFICANCE 2/	MEASUREMENT LEVEL 3/	PREDICTIVE VALUE 4/	LIMITING 5/
USFS	S	D	A	
Item 10	N	D	A	
Item 18	S	C	A	
Item 20	N	C	P	L
21	S	C	P	L
23	S	C	P	L
DEGREE	S	D	P	
QUAL	S	D	P	
Item 40	N	C	A	
46	S	C	A	
EQUIP	N	D	A	
MET	S	D	A	
Item 74	S	C	A	
76	S	C	A	
77	S	C	A	
78	S	C	A	
79	N	C	A	
80	S	C	A	
SEA	S	D	A	
Item 85	S	C	A	
86	S	C	A	L
SPEC	S	D	A	
SLOP	S	D	A	
Item 92	N	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
VEG	S	D	A	L
ACSQU	S	C	A	
ARECIP	S	C	A	

Table 13. Hypothesized Model for USFS Cost and USFS Cost per Acre Required for Completion of Reforestation (Planting) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	S	D	A	
Item 18	N	C	A	
Item 40	N	C	A	
46	S	C	A	
FSMAT	S	D	A	
MET	S	D	A	
EQUIP	S	D	A	
Item 77	S	C	A	
78	S	C	A	
79	S	C	A	
80	S	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
SEA	S	D	A	
Item 85	S	C	A	
86	S	C	A	L
SPEC	S	D	A	
ACSQU	S	C	A	
ARECIP	N	C	A	
A2RECIP	N	C	A	

Table 14. Hypothesized Model for Days and Days per Acre Required to Complete Reforestation (Planting) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING
USFS	S	D	A	
Item 10	N	D	A	
Item 13	N	D	P	
14	N	D	P	
18	S	C	A	
Item 19	N	C	P	
20	N	C	P	L
21	N	C	P	L
22	N	C	P	L
23	N	C	P	L
DEGREE	N	D	P	
QUAL	N	D	P	
Item 40	S	C	A	
46	N	C	A	
EQUIP	N	D	A	
MET	N	D	A	
Item 74	N	C	A	
76	S	C	A	
77	S	C	A	
78	N	C	A	
79	N	C	A	
80	N	C	A	
SEA	N	D	A	
Item 85	N	C	A	
86	N	C	A	
SPEC	N	D	A	L
SLOP	N	D	A	
Item 92	N	C	A	
OBS	S	D	A	
FTYPE	N	D	A	
VEG	N	D	A	L
ACSQU	S	C	A	
ARECIP	N	C	A	
A2RECIP	N	C	A	

Table 15. Hypothesized Model for Cost and Cost per Acre Required for Completion of TSI (Precommercial Thinning) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	S	D	A	
Item 13	N	D	P	
14	S	D	P	
Item 19	S	C	P	
20	N	C	P	
21	N	C	P	
22	N	C	P	
23	N	C	P	
DEGREE	S	D	P	
QUAL	S	D	P	
Item 40	S	C	A	
46	S	C	A	
EQUIP	S	D	A	
Item 74	S	C	A	
76	S	C	A	
77	S	C	A	
78	S	C	A	
79	S	C	A	
80	S	C	A	
SEA	S	D	A	
Item 88	N	D	A	L
89	N	C	A	L
90	N	D	A	L
SLOP	S	D	A	
Item 92	S	C		
OBS	S	D	A	
FTYPE	S	D	A	
Item 107	N	C	A	L
108	N	C	P	L
109	S	C	A	
110	S	C	A	
VEG	S	D	A	
ACSQU	S	C	A	
ARECIP	S	C	A	
A2RECIP	S	C	A	

Table 16. Hypothesized Model for Man-Hours and Man-Hours per Acre Required to Complete TSI (Precommercial Thinning) Operations

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 19	N	C	P	
20	N	C	P	
21	N	C	P	
22	N	C	P	
23	N	C	P	
DEGREE	N	D	P	
QUAL	S	D	P	
Item 46	D	C	A	
EQUIP	S	D	A	
Item 74	S	C	A	
76	S	C	A	
77	S	C	A	
78	N	C	A	
79	N	C	A	
-80	N	C	A	
SEA	N	D	A	
Item 88	N	D	A	L
89	N	C	A	L
90	N	D	A	L
SLOP	S	D	A	
Item 92	N	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
Item 107	S	C	A	L
108	N	C	A	L
109	S	C	A	
110	D	C	A	
VEG	S	D	A	
ACSQU	S	D	A	
ARECIP	S	D	A	
A2RECIP	S	D	A	

Table 17. Hypothesized Model for Equipment Hours and Equipment Hours per Acre Required to Complete TSI (Precommercial Thinning) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 20	N	C	P	
21	N	C	P	
22	N	C	P	
23	S	C	P	
DEGREE	S	D	P	
QUAL	S	D	P	
Item 40	S	C	A	
EQUIP	S	D	A	
Item 74	S	C	A	
76	S	C	A	
77	S	C	A	
78	N	C	A	
79	N	C	A	
80	N	C	A	
SEA	S	D	A	
Item 88	S	D	A	L
89	N	C	A	L
90	N	D	A	L
SLOP	S	D	A	
Item 92	N	D	A	
OBS	S	D	A	
FTYPE	S	D	A	
Item 107	N	C	A	L
108	N	C	A	L
109	S	C	A	
110	S	C	A	
VEG	S	D	A	
ACSQU	S	C	A	
ARECIP	N	C	A	
A2RECIP	N	C	A	

Table 18. Hypothesized Model for USFS Man-Hours and USFS Man-Hours per Acre Required to Complete TSI (Precommercial Thinning) Operations.

FACTORS[1/]	SIGNIFICANCE[2/]	MEASUREMENT LEVEL[3/]	PREDICTIVE VALUE[4/]	LIMITING[5/]
USFS	S	D	A	
Item 10	N	D	A	
Item 18	N	C	A	
Item 19	N	C	P	
20	N	C	P	
21	N	C	P	
22	N	C	P	
DEGREE	S	D	P	
QUAL	N	D	P	
Item 40	S	C	A	
46	S	C	A	
EQUIP	S	D	A	
Item 74	N	C	A	
76	N	C	A	
77	S	C	A	
78	N	C	A	
79	N	C	A	
80	N	C	A	
SEA	S	D	A	
Item 88	N	D	A	L
SLOP	N	D	A	
Item 92	S	C	A	
OBS	S	D	A	
FTYPE	S	D	A	
VEG	S	D	A	
Item 107	N	C	A	L
108	N	C	P	L
109	S	C	A	L
110	S	C	A	L
ACSQU	S	C	A	
ARECIP	S	C	A	
A2RECIP	S	C	A	

Table 19. Methods considered in the analysis which were site preparation and reforestation operations.

Site Preparation:

- Tractor and scalper
- Strip with tractor and blade
- Complete with bulldozer and blade
- Bulldozer and discs
- Whip felling
- Scarification
- Windrowing
- Helicopter with chemical spray

Reforestation (planting):

- Machine
- Hand
- Auger
- Auger and hand

models developed in this study are supplied to inform the user of the appropriate ranges of application. As Wikstrom and Alley (23) point out, the models do not guarantee accuracy since timber growing involves so many unpredictable factors that can influence cost. This study, however, has attempted to collect as much information as possible to help account for those factors and lend utility to the final results. Regardless, the equations developed here will benefit from updating as new and more reliable data becomes available. This is especially important in light of the fact that the available data collected in this study was not designed to measure cost relationships.

A basic assumption of regression analysis that is violated in this study is that the observations on the independent variables can be measured without error. As previously noted, many of the observations are based on estimates which have an associated error but as Kmenta (6) points out, measurement errors are likely to be present in most, if not all, economic observations and are generally ignored unless they are of a stochastic nature. Thus, all regression equations are assumed to have some associated error expressing the average difference between predicted values and actual observations.

With regard to causal relationships, it is important to be cautious about the interpretation of regression results. Strong relationships between variables does not prove or even imply that the independent variables are "causes" of the dependent variable (3). Causal determinations require carefully controlled experimentation to make definitive inferences, however, a "meaningful interpretation of the relationship between variables can be described in a statistical sense." (3)

The sensitivity of the dependent variable to changes in the independent can be ascertained through statistical techniques such as the use of confidence intervals and hypothesis testing to infer true population relationships. In summary, no deterministic statements about the population as a whole will be possible from this study, however, statements about what may be expected to result, on the average, will be made.

Since it was desirable to keep the models as simple as possible, in terms of the number of variables included, stepwise regression was employed to choose that set of variables most highly correlated with the dependent variable. The object is to select as few variables as possible to account for as much of the variation in the observations on the dependent variable as possible. Regression analysis relies on a correlation coefficient matrix which measures the relationship (degree of association) between all of the included independent variables and the dependent variable. Stepwise regression indicates the order in which independent variables enter the equation and how they are subsequently evaluated. The most highly correlated variable enters the equation first accounting for a certain amount (percentage) of variation in the dependent variable observations. At each step, the variable(s) entered in the previous step(s) are reexamined to determine whether they still account for a significant amount of variation. A partial F-statistic is calculated for each variable presently in the model treating it as if it were the most recent variable entered. That is, regardless of its actual point of entry, it is tested using the partial F-criterion to determine whether it still contributes to a significant reduction in variation. This is done while controlling the variation

accounted for by the other variables presently in the model. Should a variable fail the test, as evidenced by a nonsignificant partial F-statistic, it is removed from the equation. The model is "refitted" (new coefficients are calculated) and partial F's are calculated for those variables not included in the equation to determine which will account for a significant amount of that variation remaining. If another variable is present which accounts for a significant amount of the variation, it is entered into the equation. The entire process continues until no further significant reductions in variation are possible. If the assumption of a linear relationship is correct, the resulting model is guaranteed of producing the "best-fitting" straight line estimate of the sample mean due to the properties of the least-squares procedure which minimizes the sum of squared deviations between observed and predicted dependent variable values.

Several problems became apparent during the initial statistical evaluations in the study. The final methodology developed is largely a response to those problems. One problem centered around the total number of variables included in any one regression design statement. The probability of selecting at least one significant independent variable in a stepwise procedure, when in reality there are none, increases rapidly as the number of candidate independent variables increases (14). Therefore, it was desirable to keep the list of candidates to a minimum. It was also desirable to test all variables suspected of influencing the cost variable, preferably in a simultaneous manner, which would take advantage of the stepwise approach in its ability to test all variables while controlling for the effects of variables already found to be significant. This would allow for their removal should a new

variable enter the equation which reduced the significance of a previously entered variable. The SPSS multiple regression procedure allows a maximum of 100 independent variables. Pope and Webster (14) suggest that where large numbers of independent variables are involved that overall significance tests be valid to at least the .001 level and that the .05 level be used to conduct any single test such as that calculated for the partial F criterion. Therefore, parameters for inclusion and rejection of variables were established to accommodate the required levels of significance.

The number of missing values for variables included in the regression design statement also caused a problem. In order to maintain efficient (smallest variance) and unbiased (mean equal to true population parameter) estimates of the coefficients, it is desirable to eliminate entire cases which include missing values for variables under consideration. Unfortunately, the probability of receiving a reporting form with no missing values is quite low, if only because of the questionnaire's length and complexity. If it were possible, a regression run that included all the variables included in the questionnaire (case) would probably result in no cases being read because of the case-wide deletion option. In fact, in several instances, runs attempted using the entire variable list included in the hypothesized models resulted in only one case being read. Since the primary objective of this study is to develop models that are applicable over a wide range of circumstances, it was considered advantageous to develop models using as many cases as possible to obtain an adequate representation of the possible situations that are likely to occur in a given locale. Consequently, judicious

selection of variables to be included in the regression was required to maintain the desired representation by identifying the limiting variables (variables with a large number of missing values, Tables 3 through 18) from the FREQUENCIES output. Complete elimination of the limiting variables was not considered appropriate since they were suspected of having some influence on cost. The methodology that follows appears to substantiate the suspected influence.

Another problem related to missing values became apparent during the analysis. The data base would change each time a different variable list in the regression design statement was used. This made comparisons of different models extremely difficult as it was generally easier to account for a significant amount of the variation in small sample sizes than in larger ones. This issue is also addressed in the discussion of the methodology.

Preliminary Theoretical Considerations

As stated above, variables having a large number of missing values are considered limiting because when entered into the regression design statement, they reduce the number of cases (observations) included in the data base. Consequently, the estimates (coefficients) generated are less likely to appraoch the values of the true population parameters. This consequence is especially important when the sampling distribution is at all different from the normal and hypothesis tests are to be made. Since confidence intervals and significance tests are computed assuming a normal distribution, it is desirable to have the sampling distribution be, or at least approach, normality if any value is to be placed in the statistics. By increasing the sample size, or in

this case, the number of observations, the sampling distribution does approach the normal as described by the Central Limit Theorem. The estimates also approach the true population parameters due to the property of consistency for point estimates which guarantees that estimates improve with increased sample size.

Bias, the difference between the true population value and the estimate, is reduced as is the variance associated with the estimate as sample size increases. As Kmenta (6) emphatically points out, the additional reliability of estimates resulting from increased sample size is well worth the cost and effort required to obtain them.

Another desirable property of estimates is unbiasedness. An unbiased estimate is one whose mean is equal to the true population parameter, i.e. the expected value of the estimate is equal to the value of the population parameter to be estimated. Unbiased estimates, however, may display considerable variance leading to estimates which frequently over or underestimate the true population value while "on the average," they are still equivalent. The property of efficiency addresses this variance issue. An efficient estimate is one having the smallest variance among all possible unbiased estimates. Verifying that the estimate does, in fact, have the smallest variance, however, is no small task. The Cramer-Rao inequality theorem allows the determination of the lowest variance possible for any unbiased estimate, provided the distributional characteristics of the parent population are known. Whether the lower bound can or cannot be achieved by an unbiased estimate introduces yet another perplexing problem. Fortunately, frustrations resulting from an inability to properly assess efficiency may be

eased by limiting the class of unbiased estimates to those which are linear functions of the sample observations. This best linear unbiased estimate (or BLUE) is identical to the estimate produced by the least-squares approach utilized by SPSS and is efficient assuming the classical normal linear regression model (6). Efficiency, by itself, is not a desirable characteristic of an estimate since minimum (in fact, zero) variance could be attained by ignoring the sample evidence and simply using a constant. The property of sufficiency, however, requires the utilization of all sample observations in the calculation of parameter estimates because each additional observation contributes more information and details concerning the population for which the sample is intended to represent. Sufficiency, moreover, is a necessary condition for the realization of efficiency (11) i.e., an unbiased estimate cannot be efficient unless it has considered all of the population parameter information contained in the sample.

Increasing the number of observations also introduces more variation (as long as most are different from the mean) while simultaneously reducing the variance in the sample of dependent and independent variable values. Changes in the value of the dependent variable from one observation to another (variation) are due primarily to changing independent variable values and partly due to the effect of a random disturbance. As sample size increases, it's possible that "mean" combinations of values, not yet represented, will enter contributing to the increased variation. Likewise, values will enter which closely resemble the average condition reducing the dispersion (variance) of dependent variable values for a given set of independent variable values.

Regression analysis attempts to explain the total amount of variation in the dependent variable observations (Y_i's) by identifying the variation attributable to variations in the independent variable observations (X_i's) and that which is due to the random element (chance). Total variation, defined as the sum of the squared deviations between the observations (Y_i) and the mean ($\bar{Y}$), can be partitioned into two components; 1) variation accounted for by the regression line and its estimate ($\hat{Y}_i$), and 2) the remaining variation described by the difference between the predicted value ($\hat{Y}_i$) and the actual observation (Y_i). Mathematically, the relationship is written

$$\underbrace{\sum_{i=1}^{n} (Y_i-\bar{Y})^2}_{SST} = \underbrace{\sum_{i=1}^{n} (\hat{Y}_i-\bar{Y})^2}_{SSR} + \underbrace{\sum_{i=1}^{n} (Y_i-\hat{Y}_i)^2}_{SSE}.$$

The object of regression analysis (method of least squares) is to minimize the sum of the squared deviations between the predicted value ($\hat{Y}_i$) and the means ($\bar{Y}$) (SSR) by estimating the population parameters which describe the relationship between the dependent variable and the independent variables. According to the equation the degree of success is indicated by the residual in the sum of the squared deviations between predicted values ($\hat{Y}_i$) and actual observations (Y_i) (SSE). Ideally, this should be a relatively small number estimating the stochastic nature of the model. That is, for every value possible in each of the independent variables there is a probability distribution of Y_i values implying that Y_i can never be forecast exactly. However, violations of basic assumptions, aversion of desirable estimate properties and/or errors in model specification all contribute to the inflation of SSE relative to SSR.

Two important model evaluation criteria involve the component parts of sample variation decomposition. "Goodness of fit" is measured by the coefficient of determination (R^2), defined as the ratio of explained variation (SSR) to total variation (SST). It provides a measure of predictive accuracy in terms of the percentage of total variation accounted for by the model. Given the model, it is reasonable to expect this value (R^2) to drop as more variation is introduced via the consideration of additional cases. Conversely, SSE will probably increase since the original model can't account for the new variation represented in the Y_i's. The standard error of the estimate,

$$\sqrt{\frac{SSE}{n-2}}$$

provides a measure of the absolute amount of unexplained variation. Since it is the standard deviation between the actual observations (Y_i) and the predicted values ($\hat{Y}_i$), the standard error term is more appropriate for comparisons among several different models than is the coefficient of determination (R^2) which is not standardized or corrected for the number of observations. Both measures will be referenced, however, to give the user sufficient information to judge the results. Understanding the relationship between the two and the number of observations is essential, if one is to follow the logic embodied in the methodology used to develop the cost models.

Because sample size has such a dramatic effect on the quality and reliability of the estimates, consideration of as many cases as possible was a major objective in the model development procedures. It was viewed as being extremely important to the realization of an accurate model, applicable to a wide range of site and stand characteristics

commonly occurring in Region 6. In general, the trade-offs between predictive accuracy and adequate representation resulting from changes in the sample size were evaluated at each step in the analysis.

Criteria mentioned above, as well as examinations of relevant ranges of variation in the selected explanatory independent variables and the estimated regression coefficients were included in the investigations to determine the value of the model in prediction. A detailed description of the process is included in the following section.

Another area of concern alluded to earlier deals with specification errors. Incorrect formulation of the regression model or disregard of the underlying assumptions governing the procedure constitute specification errors. Full specification of the classical normal linear regression model includes; 1) the regression equation of the form

$$Y_i = \beta_o + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots \beta_k X_{ik} + \varepsilon_i,$$

where Y denotes the dependent variable, the X's represent the independent or explanatory variables, the β's denote the population parameters to be estimated, and ε is the stochastic disturbance, and 2) the following basic assumptions taken to apply to all observations:

a) Normality: ε_i is normally distributed,

b) Zero mean: $E(\varepsilon_i) = 0$,

c) Homoskedasticity: $E(\varepsilon_i^2) = \sigma^2$,

d) Nonautoregression: $E(\varepsilon_i \varepsilon_j) = 0 \; (i \neq j)$,

e) Nonstochastic X: X_i is a nonstochastic variable whose range of possible values remains fixed such that for any sample size,

$$\frac{1}{n} \sum_{i=1}^{n} (X_i - \bar{X})^2$$

is a finite number different from zero (6). Since the true mathematical form of the relationship between the X's and Y has to be assumed, parameter estimates are derived using the observations in a sample. The value of the stochastic disturbance is then estimated for each X, Y pair using their respective parameter estimates. For each observation, X_i, the assumptions require the disturbance be normally distributed around mean zero with constant variance throughout the possible range of X_i values. Furthermore, the covariance (degree to which one value influences another) between any two disturbances will be zero, i.e. ε is a random independent variable. And finally, all explanatory variables must be non-random with their possible range of values remaining constant through repeated samples such that, the individual values (observations) of X_i's are not all equal and their sample variance will not grow or decline without limit as the sample size varies. An interesting extension of these assumptions is since Y is a linear function of ε, a normally and independently distributed random variable whose distribution can be fully determined by two parameters, the mean and variance, Y is also a normally and independently distributed random variable with its mean equal to

$$E(Y_i) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \cdots + \beta_k X_{ik}.$$

Therefore, the regression problem of estimating the population parameters is identical to estimating the mean of Y_i. That is, since Y_i is a random, normally distributed variable with a probability distribution associated with each value of X_i, the estimation of the regression coefficients simultaneously provides an estimate of a parameter describ-

ing Y_i's distribution, namely its mean, through which passes the sample regression line. This equality provides a convenient interpretation of the regression coefficients as follows:

β_o = The mean of Y_i when the value of each independent variable is zero;

β_k = The change in $E(Y_i)$ for a unit change in the value of variable X_k, holding the remaining independent variable values constant.

The last condition may seem to imply the possibility of estimating regression coefficients for a given explanatory variable by considering only those observations obtained while the remaining variables are held constant. If it is, in fact, appropriate to estimate parameters in this fashion, the theory would suggest the inappropriateness of a multiple regression design in the first place. The specification of a multiple regression design implies that the variation in Y is dependent on the mutual (not necessarily equal) effect of two or more explanatory variables. Since the population parameters "recognize" the effect of each variable, estimates which exclude a relevant factor in their calculation are biased and inconsistent. On the other hand, estimates which include one or more irrelevant variables in their calculation are unbiased and consistent but inefficient. Variance estimates including the specification error share the same properties but since they are unbiased, significance tests and confidence intervals for the regression parameters are valid (6).

Since BLU estimates of the regression coefficients require minimum variance, a genuine concern involves the consequences of the hypothesized models in relation to specification errors. At present, the correct (true) specifications of models designed to yield site-specific information is not known. It is, therefore, desirable to test specific hypotheses concerning the suspected relationships and avoid specification errors by allowing for the possibility of finding none. Specifically, the test should assess the consequences of additional explanatory variables on (Y_i). For example, if variable X_{k+1} was being considered for admission in the regression equation, the test

$$H_0 = \beta_{k+1} = 0$$

versus the alternative that H_0 if not true would be an appropriate criterion for establishing the correct model specification. If the addition of variable X_{k+1} contributed to a significant reduction in the unexplained variation, then the null hypothesis would be rejected and X_{k+1} would enter the regression equation.

The stepwise procedure utilized by SPSS subroutine REGRESSION performs this same test in addition to two others using the partial F-statistic to evaluate the significance of each test. In fact, significance tests made in the stepwise procedure are more comprehensive than the relatively simple test proposed above. Specification errors are avoided because not only are "candidate" variables tested, but each variable already included in the equation is tested again to verify that it continues to contribute to a significant reduction in the unexplained variation. Should a variable fail the test, it is removed from the equation and placed among the candidate variables where it is possible for it to enter again.

Theoretically, when significance levels are set at a relatively high standard, the testing procedures employed in the stepwise approach should guarantee the elimination of errors in model specification. This is only true, however, when the procedure has the opportunity to test all possible influential factors. Therefore, it was considered advantageous to include as many of the postulated variables in the hypothesized model as possible in the list of candidate variables for each regression run.

Model Development Illustrated

A series of steps were necessary to thoroughly investigate the factors postulated as having an effect on the determination of the dependent variable. To illustrate the methodology employed in this study, models expressing the total and per acre cost (amount paid to the contractor) required to complete reforestation (planting) operations are presented as an example. The approach is designed to address those problem areas discussed earlier and arrive at a reliable model in an expeditious manner.

Including the dummy variables, a total of 89 factors were suspected of possibly influencing the cost of the operation (Table 9). An examination of the scatterplots and statistics produced by the SPSS subroutine SCATTERGRAM was not very conclusive, as only 4 of the 19 continuous variables included in the hypothesized model indicated a definite linear trend. No nonlinear relationships were apparent, however, since large number of observations (216) caused some difficulty in discerning the presence or absence of patterns and trends. Pearson product-moment correlation coefficients calculated with SPSS subroutine CORR supported the conclusions concerning the 4 variables identified

in the scatterplots. That is, a high degree of association exists (at the 5% probability level) between the dependent variable and each of the 4 independent variables.

Test regressions using only those significant variables identified in the correlation analysis were not satisfactory in explaining variation. This result was anticipated however, since no dummy variables were included that may have accounted for any confounding influences such as the method employed. Another approach that failed to account for significant amounts of variation involved a sequence of regression runs. The first of which considered only selected continuous variables deemed especially important to the determination of the dependent variable. Each subsequent run tested for the significance of a group of dummy variables from a particular category such as type of equipment used. The group was retained if any single member was included in the final equation, otherwise it was removed. Each of the following runs considered another group of dummy variables in this fashion until the list of hypothesized variables was exhausted. Ideally, this procedure would satisfy the inspection of all hypothesized influences, however, the approach was abandoned due to a number of problems that became apparent during its trial. This procedure turned out to be extremely expensive and time consuming. Further, as variables were entered and removed according to their significance in the previous run, the number of cases (observations) would change making comparisons between models very difficult. For example, if one of the "new" variables came into solution (was significant) but the number of observations also decreased, it was impossible to ascribe the change in standard error and the R^2 value to the inclusion of the new variable. Instead the change could be due

to the smaller sample having less variation. Another problem involved the removal of nonsignificant variables from consideration in subsequent runs. It's quite possible after a certain amount of variation is accounted for, i.e. some confounding effects removed, those variables that were eliminated in previous runs might now be significant. The utility of the stepwise procedure lies in its ability to enter and remove variables based on a test that accounts for the variation already explained. Obviously, variables that have been eliminated in previous runs don't have the opportunity to be considered in subsequent runs where they might have been significant. Thus, the approach was abandoned.

A technique that did prove to be very useful for the identification of significant factors involved a total of 3 regression runs. Because the first included the entire hypothesized variable list, the number of cases read would be the smallest of any subsequent run. The second run also includes the entire variable list but population means are substituted for missing values resulting in the entire data file being used to make estimates. Even though this introduces some bias, the objective was to identify significant variables when full information is available i.e., when there are no missing values and the number of cases read is the greatest. Significant variables from both runs are entered into the third, usually resulting in a model with good predictive accuracy based on a large number of observations. This technique lead to the approach finally adopted in this study.

Specifically, the approach was designed to obtain as many observations as possible in the final model while simultaneously sacrificing an acceptable amount of predictive accuracy. Recognizing that increased

sample size would introduce more variation resulting in consequent losses in predictive accuracy, the decision was made to evaluate the trade-off by comparing the percentage change in sample size with the percentage change in standard error of the estimate. Generally, if the change in sample size was greater than the loss in predictive accuracy, the model was considered an improvement. However, other criteria such as the number of variables and confidence interval ranges were also considered before making a final determination.

Final models presented in this paper (Table 20 through 58) are selected from runs made in the following manner. The first includes all variables in the hypothesized models establishing a lower limit with regard to the number of observations. Normally, this run exhibits the best prediction qualities since it is based on a small number of cases. All subsequent runs are compared to it. Each subsequent run includes one or a group of limiting variables in an attempt to assess the consequences of their inclusion in terms of predictive accuracy and number of cases considered.

Results of the first run on reforestation cost per acre (Table 20) are not bad considering the absolute number of cases (94) used for the estimates but that figure accounted for only 44% of the total number available. Of these cases considered, approximately 18% of the total variation was accounted for by those jobs that completed all terms of the contract but required a time extension (Degree 1). Another 17.5% of the total variation was removed by contracts awarded in 1977 (Item 14). The coefficient indicates that while all other variables in the equation are held constant, contracts awarded in 1977 cost, on the average, $9.25 per acre more than those awarded in 1976. Winema,

Fremont, and Coville National Forests have adjustments of $-20, $-29, and $-22, respectively in their per acre costs. Per acre costs appear to decrease at a increasing rate as the number of acres increases (ACSQU). The extremely small coefficient indicates, however, that the decrease is of negligible importance. Costs decrease, on the average, by $2 for each bid received while increasing by $1.12 for every year the contractor has been in business. Each seedling planted increases per acre costs by approximately $.03 (Item 85). The presence of small saplings and brush appears to increase costs by $9.16. The last two variables (USFS 16 and VEG 4) could be dropped since they only account for approximately 3% of the total variation.

Tables 21 and 22 show the results of the second run for total cost and per acre costs, respectively. Items 19 through 25 were the only limiting variables included in this run resulting in approximately 54% (as compared to the previous 44%) of the total number of observations being read. Both Items 19 and 23 were significant in both models but contribute relatively little in the total cost model. Predictive accuracy was improved in the per acre model.

As expected, the year the contract was awarded is important in both models. Adjustments for contracts awarded in Wallowa-Whitman, and Winema National Forest are included in the per acre model while the total cost model only adjusts for the Mt. Hood National Forest. Since vegetation descriptions were not included in this run, obstacle descriptions were significant in describing impediments to progress (OB 55 and OB 54). The use of powered hand tools (EQUIP 2), principally augers, increases the per acre cost by $7.34.

Table 20. Reforestation, Cost per Acre Model Summary*

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
49.45	18.66	94	75.76	9.7826	DEGREE 1	30.5511	.18415	19.6105	41.4917	.0532	.2256
					Item 14	9.2577	.17547	4.664	13.8510	.3830	.4887
					USFS 15	-20.2053	.15498	-25.3943	-15.0163	.4468	.4998
					ACSQU	-.000015	.04669	-.00002	-.000009	145291.5957	389339.3033
					Item 23	1.1205	.05943	.6796	1.5613	8.0957	6.1401
					Item 19	-2.0432	.03547	-3.0022	-1.0842	4.7766	2.5951
					USFS 2	-29.1381	.02310	-49.4356	-8.8406	.0106	.1031
					Item 85	.02784	.02546	.01202	.04366	452.7021	151.5735
					DEGREE 2	-16.4635	.02359	-25.8347	-7.0923	.0638	.2458
					USFS 16	-22.6310	.01502	-42.6168	-2.6450	.0106	.1031
					VEG 4	9.1612	.01427	.8654	17.4531	.0745	.2639
					CONSTANT	44.5603		36.1360	52.9846		

*Utilizes data base prior to final edit.
Data base includes 68 contracts awarded in 1975 and 1978.

Table 21. Reforestation, Total Cost Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
7835.95	7817.14	79	94.66	1906.9223	Item 77	49.7038	.79876	44.6805	54.7272	166.9367	200.5145
					ACSQU	-.0150	.05930	-.0192	-.0107	67564.9873	229921.5402
					USFS 4	6403.5016	.02822	3576.3387	9230.6646	.0253	.1581
					Item 14	2550.6593	.02106	1546.9317	3554.3869	.4430	.4999
					Item 19	-358.7704	.01575	-535.5915	-181.9492	4.7975	2.8706
					Item 23	189.4052	.01601	115.3261	263.4844	7.6076	6.1403
					Item 13	-3344.0449	.00401	-6199.0638	-489.0259	.0253	.1581
					OBS 4	-1535.3399	.00347	-2970.6375	-100.0422	.1772	.3843
					CONSTANT	-105.2262		-1262.2506	1051.7982		

Table 22. Reforestation, Cost per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Interval Upper	Variable Means	Variable Std. Dev.
49.28	19.05	79	83.84	8.1439	DEGREE 1	33.4478	.27162	22.8051	44.0905	.0506	.2206
					Item 14	19.0093	.24815	14.7387	23.2798	.4430	.4999
					USFS 13	12.3224	.11735	3.6316	21.0132	.0633	.2450
					Item 19	-1.6025	.08679	-2.3426	-.8625	4.7975	2.8706
					Item 23	.8789	.02868	.4850	1.2729	7.6076	6.1403
					USFS 15	-11.6792	.03641	-16.2960	-7.0623	.4810	.5028
					EQUIP2	7.3396	.02521	2.1643	12.5148	.3797	.4884
					Item 74	- .3528	.01340	- .6333	-.0723	7.1139	7.3815
					OBS 5	-18.0027	.01078	-34.7459	-1.2594	.0127	.1125
					CONSTANT	44.9504		39.8215	50.0793		

As expected per acre costs decrease with increases in the number of multiple areas (Item 74). Not anticipated, however, was the decrease in total costs for contracts awarded in the last quarter of the fiscal year (Item 13). The number of acres treated is always expected to be one of the first variables to enter any of the total models. Its coefficient should approach the mean per acre cost of the population as does the one in this case. The constant (Y-intercept) has no meaningful interpretation in the total models and should, as in this instance, be nonsignificant.

Item 86 (months since site preparation completed) was the only limiting variable included in the third run (Tables 23 through 26). Its impact was expected to be significant since more impediments to progress in the form of brush and groundcover were expected to accrue over time. The hypothesis, however, was not supported by the results reported here, since it was not significant in either model. Estimates developed with and without USFS designation were made. Tables 24 and 26 (total and per acre, respectively), are presented here to show the reduction in predictive accuracy resulting from the elimination of national forest designations. Including USFS designations probably masks the real physical causes of cost variation. For example, the Winema National Forest (USFS 15) was the third variable to enter the equation (Table 25), whereas the other model (Table 26) has large rocks and/or stumps (OBS 4) entering on the third step. One possible explanation is areas reforested on the Winema may have had progress impeded by large rocks and/or stumps.

Variables describing the quality of work performed are difficult to interpret (QUAL 1 and QUAL 2). Apparently any job judged as being

of less than excellent quality are less expensive to complete. This seems logical. Both variables, however, contribute very little to the explanation of variation and can therefore, be deleted.

Hand planting is significant in all three models indicating less expense relative to the entire population. Its contribution to the removal of variation in the total model is, however, negligible and it may be dropped.

The percentage change in number of cases exceeds the loss in predictive accuracy as measured by the percentage change in standard error of the estimate between models presented in Tables 23, 25, and Tables 21, 22. Confidence intervals are somewhat wider in Table 25 than those in Table 22 for variables common to both. This result is expected however, due to the significant increase in number of observations.

Tables 27 and 28 show the results of including the dummy variables describing vegetation (VEG) for per acre and total costs respectively. In comparing Table 28 and Table 25, the percentage change in observations exceeds the percentage change in standard error of the estimate by enough of a margin to warrant selecting the per acre model utilizing 129 cases (88% of the total) (Table 28). The percentage change in standard error of the estimate exceeds the percentage change in the number of cases, however, for the total cost model (Table 27). Therefore, the total cost model using 105 cases to develop estimates (Table 23) is the recommended model.

These same steps were employed to evaluate all models developed in this study. Thus, the recommended models appearing in Tables 29 through 58, in the next chapter, represent estimates derived using the largest data base possible without sacrificing an unacceptable amount of predictive accuracy.

Table 23. Reforestation, Total Cost Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
7747.41	7033.85	105	89.11	2416.0152	ITEM 77	52.1980	.79297	48.2173	56.1788	124.1624	142.7810
					USFS 15		.02154			.4829	.3619
					DEGREE 1		.01918			.2332	.0571
					Item 14	2464.2392	.01586	1464.4478	3464.0307	.4985	.4381
					MET 119	-3448.9155	.01296	-4588.3306	-2309.5004	.4337	.7524
					USFS 4	4490.5863	.00809	2238.7443	6742.4284	.2140	.0476
					-DEGREE 1		-.00468			.2332	.0571
					-USFS 15		-.00505			.4829	.3619
					USFS 13	3797.2968	.01103	1564.7696	6029.8240	.2140	.0476
					SPEC 4	2264.5582	.00703	447.1745	4081.9418	.2666	.0762
					USFS 1	-5927.2860	.00646	-10859.174	-995.3982	.0976	.0095
					OBS8	3955.2232	.00572	457.5589	7452.8876	.1373	.0190
					CONSTAND	1223.7619		85.0372	2362.4866		

Table 24. Reforestation, Total Cost Model Summary without USFS Designations

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
7747.41	7033.85	105	87.23	2589.7364	Item 77	51.3360	.79297	47.0709	55.6010	142.7810	124.1624
					Item 14	1758.2978	.02149	663.5106	2853.0850	.4381	.4985
					MET 119	-2059.0920	.02769	-3305.2421	-812.9419	.7524	.4337
					Item 76	-109.6061	.00985	- 174.3993	-44.8129	10.3333	8.4429
					DEGREE 1	2890.8622	.01234	596.0346	5185.6897	.0571	.2332
					OBS 2	4862.7857	.00792	948.7710	8776.8004	.0190	.1373
					CONSTANT	2071.3119		522.4282	3620.1956		

Table 25. Reforestation, Cost per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
54.35	19.99	105	79.46	9.6859	MET 119	-22.6285	.20404	-27.8650	-17.3920	.4337	.7524
					Item 14	17.7204	.21883	13.1985	22.2423	.4985	.4381
					USFS 15	-15.6539	.10601	-21.5820	-9.7258	.4829	.3619
					DEGREE 1	21.8008	.07486	12.9149	30.6868	.2332	.0571
					USFS 13	22.7113	.04304	13.2519	32.1708	.2140	.0476
					Item 85	.0221	.04227	.0082	.0360	160.5008	486.3048
					SLOP 2	7.9642	.01603	3.4987	12.4297	.4737	.3333
					OBS 4	-9.9532	.01531	-17.0234	-2.8831	.3516	.1429
					QUAL 2	-10.8368	.01786	-16.6546	-5.0190	.4493	.2762
					QUAL 1	-10.1402	.01930	-16.0528	-4.2276	.5022	.4857
					USFS 14	-14.0564	.01180	-25.1306	-2.9823	.1923	.0381
					USFS 1	-25.0624	.01316	-45.2854	-4.8394	.0976	.0095
					OBS 8	16.7652	.01213	2.4012	31.1292	.1373	.0190
					CONSTANT	63.3348		54.0292	72.6404		

Table 26. Reforestation, Cost per Acre Model Summary without USFS Designations

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Interval Upper	Variable Means	Variable Std. Dev.
54.35	19.99	105	71.72	11.1829	MET 119	-22.8851	.20404	-28.7927	-16.9775	.7524	.4337
					Item 14	16.3450	.21883	11.1746	21.5154	.4381	.4985
					OBS 4	-13.0483	.09569	-20.2284	-5.8683	.1429	.3516
					DEGREE 1	22.4634	.04581	12.3290	32.5977	.0571	.2332
					Item 76	-.7566	.05752	- 1.1039	-.4093	10.3333	8.4429
					Item 85	.0272	.02519	.0125	.0418	486.3048	160.5008
					SLOP 1	-6.4467	.01619	-12.7066	-.1868	.2000	.4019
					QUAL 2	-12.3239	.01481	-19.0674	-5.5805	.2762	.4493
					QUAL 1	-10.7160	.02251	-17.2637	-4.1684	.4857	.5022
					Item 13	-29.1959	.01662	-53.8577	-4.5341	.0095	.0976
					CONSTANT	69.7753		59.1747	80.3759		

Table 27. Reforestation, Total Cost Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
9504.02	9414.21	129	90.40	3011.8379	Item 77	55.0053	.8135	46.3920	63.6187	185.0078	200.0498
					ACSQU	-.01875	.0455	-.02507	-.01242	73937.5504	202224.5886
					OBS 12	-4176.6729	.0094	-6780.6128	-1572.7340	.0465	.2114
					USFS 4	4054.0324	.0080	1250.5008	6851.5641	.0388	.1938
					Item 14	1997.8053	.0075	914.5398	3081.0101	.0388	.1938
					MET 119	-2140.9058	.0083	-3487.2594	-794.5521	.7829	.4138
					Item 40	1.5206	.0053	.5480	2.4932	985.9070	1010.8155
					USFS 1	-8742.9525	.00615	-14986.491	-2499.4129	.0078	.0880
					CONSTANT	97.8072		-1248.7208	1444.3353		

Table 28. Reforestation, Cost per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
53.36	19.08	129	67.5	11.2847	MET 119	-23.4612	.19423	-28.7831	-18.1353	.7829	.4138
					Item 14	15.0558	.19944	10.9796	19.1320	.4496	.4994
					USFS 15	-14.5093	.07868	-19.1381	-9.9674	.2946	.4576
					DEGREE 1	24.5234	.07127	14.7059	34.3411	.0465	.2114
					USFS 13	23.8441	.04686	13.4032	34.2851	.0388	.1938
					Item 85		.03558			492.6822	176.8928
					USFS 1	-32.2053	.01418	-55.1822	-9.2284	.0078	.0880
					OBS 8	21.5256	.01326	5.3201	37.7312	.0155	.1240
					SLOP 2	7.5641	.01449	3.0710	12.0571	.3178	.4674
					-Item 85		-.00944				
					USFS 14	-13.4486	.01647	-24.3141	-2.6031	.0388	.1938
					CONSTANT	65.2053		59.8534	70.5572		

CHAPTER IV
Results and Recommendations

Results and recommendations presented in this chapter represent the culmination of literally hundreds of regression runs which sought to investigate the influence of a large number of variables on a total of 12 dependent variables in three activity categories. The results are by far not the final solution to predicting costs since time and financial limitations prohibited the testing of equations to determine their reliability, range of application and sensitivity to changing values of the independent variables. No extensive residual analysis has been completed which is the primary reason models designed to predict totals were developed. Though unconfirmed, it is possible that the variance associated with small acreage jobs is greater than that for large acreage jobs, which if true, would violate the basic assumption of variance homogeneity in the per acre estimates.

Models presented in this study do, however, represent the "best" obtainable given the stratifications used and the criteria employed to deal with changing sample sizes. In addition, the number of regression runs made for each dependent variable in each category allows some generalizations concerning significant factors. Significant factors are generally discussed in the order of their appearance in the hypothesized model. Directional impacts, as denoted by coefficient signs, are noted when a consistent trend is observed. The reader should recall, however, that coefficients, including their respective signs, are adjusted for the variables included in the final equation. Therefore, some general trends observed may be a response to variation that remains unaccounted for after several variables have already removed some confounding effects.

Effectiveness of the recommended models as predictive tools will also be addressed. In particular, a discussion of the appropriateness of each model will respect to: 1) representation of significant factors, 2) ranges of application, and 3) improvement in predictive accuracy relative to existing methods will be included. As stated above, significant factors are identified through examination of all the runs made for a particular dependent variable. Ideally, the final model should include many, if not all, of the significant factors. Limiting or posteriori significant variables, however, purposely may be eliminated in the final model if their inclusion encumbers the applicability of the model. Ranges of application are determined by continuous variables since the mean and standard deviation of dummy variables is difficult to interpret. Acreage will be used to define the appropriate range of application for each model developed in this study. The user should nevertheless, reference the mean and standard deviation of each continuous variable in the final model to verify the model's applicability to the specific situation.

Assuming that averages are, indeed, the best estimate managers currently have for assessing costs, every model presented here represents an improvement in predictive accuracy. Means and standard deviations of the dependent variable for the "population" (sample) used to make the estimates are presented for each model. In effect, these two parameters describe the reliability associated with estimates based on the use of averages while the model standard error described the reliability of estimates computed with the equation. Percentage differences between the standard deviation and the standard error are discussed to show the relative improvement in predictive accuracy gained by use of the models verses averages.

Site Preparation Model Development Results

A total of 50 observations remained after the final edit which included the seven methods used to complete the operations listed in Table 19. General observations concerning factors having a significant influence on total and per acre cost determination are based on the results of 12 regression runs. As expected, the number of man-hours required to complete the operation (Item 40) was an important variable since its magnitude alone gives some indication of the problems and scope of the job at hand. Since site preparation is largely a capital intensive operation, total equipment hours required (Item 46) was expected to be more influential than man-hours, however. This was not the case. Type of equipment used (EQUIP) had a substantial impact on the removal of variation and cost determination. In particular, man-powered hand tools (EQUIP 1) and large heavy machinery (EQUIP 6) were the only significant dummy variables in the equipment-type category and always had a negative and positive, respectively, influence on total and per acre costs. Only three of the seven methods commonly utilized to complete site preparation were significant. The use of a tractor and scalper (MET 11) the practical whip felling (MET 18) always had a negative coefficient when included in the equations while complete site preparation with dozer and blade (MET 14) was always associated with a positive coefficient. The number of acres treated (Item 77) was expected to be more important than the runs indicated it was as it was only significant in four runs. In each case, however, it had a negative coefficient pointing to the possibility of scale economics between costs and total number of acres treated. Miles from all weather roads (Item 80) was the only variable describing accessibility that was important, however. The respective coefficients as well as the correlation coefficient all in-

dicate an inverse relationship which is difficult to explain logically. Slopes greater than 9-15% (SLOP 2) always had a positive effect on costs while elevation (Item 92) indicated an inverse relationship. Descriptions of impediments to progress (OBS) were very important in most of the runs. No impediment (OBS 1) always had a negative effect on cost while streams and/or gullies always had a positive effect. Large racks and/or stumps (OBS 4), slope (OBS 9), and inclement weather (OBS 12) each occurred only once with negative, and positive coefficients, respectively. Operations in the ponderosa pine forest type (FTYPE 12) were always cheaper relative to the other forest types in the region. Finally, though only occuring in three equations, the reciprical of acres (ARECIP) and acres squared (ACSQU) always had negative coefficient, again indicating the presence of scale economics for large jobs.

In summary, cost models for site preparation were most sensitive to the method and/or equipment used to complete the job and site characteristics. In particular, complete site preparation with dozer and blade was by far the most expensive method employed. Scarification, windrowing, whip felling, and bulldozer with discs were from most to least expensive to complete all relative to the reference, strips with bulldozer and blade.

No significant difference in costs between '76 and '77 contracts is evident nor was fiscal quarter important. Economics of scale do, however, seem to prevail.

The recommended model (TABLE 29 & 30) include all significant factors with the exception of forest type. Complete site preparation with bulldozer and blade (MET 14) accounts for approximately 4% of the total variation and indicates the greater expense to be incurred by its implementation. Recalling that all coefficients are adjusted for the

variables that finally appear in the equation, helps explain the non-sensical nature of the signs for some of the coefficients in the model. For example, one would not expect costs to decrease as the number of miles from all weather roads (Item 80) increases nor would costs decrease when no impediment to progress exists (OBS 1), thus illustrating the limited importance of interpretations concerning coefficients and their respective signs. The value of the per acre model for predictions is lowered because it includes the occurrence of inclement weather (OBS 12) which explains 4% of the total variation in the sample. The user should assess the probability of inclement weather to determine the value (0 or 1) of OBS 12.

In terms of standard error, the model is the best cost per acre estimate of all the runs. It represents a 58% improvement in predictive accuracy over "average" estimates. The combination of ASCQU and the constant allows its application to many situations for ranges of 1 to 420. The total cost model is appropriate for predictions if the user assumes the quality of the job will be excellent, thereby causing QUAL 1 to drop out since its value would be zero. A 61% improvement in accuracy is obtained by use of the model. It is also applicable to jobs of less than 420 acres.

Significant factors affecting the number of man-hours required to complete site preparation were identified through the inspection of 14 regression runs. National forest designations (USFS) consistently reduced the standard error of model estimates and the remaining variation. As mentioned above, however, this may have the effect of masking physical characteristics that are unique to that forest. As in cost determination, type of equipment used was very important; however, non-powered hand tools

Table 29. Site Preparation, Total Cost Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
7222.76	6179.96	46	88.39	2387.7280	ACSQU	.0321	.36535	.0252	.03900	53636.0652	127632.9101
					MET 112		.07129			.0435	.2062
					VEG 2		.05392			.1739	.3832
					ARECIP	-273973.63	.07014	-351390.60	-196356.65	.0115	.0106
					-MET 112		-.04081			.0435	.2062
					Item 80	-1006.8191	.11163	-1269.7341	-743.9042	1.5217	3.6560
					Item 92	-1.9459	.05899	-2.6468	-1.2450	4141.4130	1204.5490
					EQUIP 6	2944.3571	.05282	1350.2565	4538.4578	.4348	.4012
					QUAL 1	-2897.0324	.03794	-4818.2794	-975.7854	.7391	.4440
					-VEG 2		-.01877			.1739	.3832
					OBS 1	-5540.8580	.05653	-7505.2250	-3576.4909	.3913	.4934
					SLOP 2	2908.6717	.02224	1104.8753	4712.4680	.3043	.4652
					OBS 9	-3380.2376	.01622	-5567.2744	-1193.2008	.2174	.4170
					OBS 4	-4007.9959	.02641	-6891.8064	-1124.1854	.1304	.3405
					CONSTANT	21651.834		17582.192	25721.476		

Table 30. Site Preparation, Cost per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
54.70	32.77	46	86.44	13.6834	Item 10		.28911			.4130	.4978
					Item 77		.14676			168.8478	160.2649
					OBS 1	-21.8167	.11663	-31.6920	-11.9415	.3913	.4934
					SLOP 2	23.3177	.09835	13.5720	33.0635	.3043	.4652
					Item 80	-4.1424	.03976	-5.6314	-2.6534	1.5217	3.6560
					Item 92	-.0075	.04728	-.0118	-.0031	4141.4130	1204.5490
					-Item 10		-.02680			.4130	.4978
					OBS 12	50.7782	.04098	29.3406	72.2158	.0652	.2496
					MET 14	21.2072	.04249	8.9458	33.4686	.1739	.3832
					-Item 77		-.01923			168.8478	160.2649
					ACSQU	-.00004	.02496	-.00009	-.00002	53636.0652	127632.9101
					Item 40	.0151	.02036	.0046	.0255	407.8478	483.6755
					EQUIP 6	10.4655	.02558	1.0862	19.8449	.4348	.5012
					EQUIP 1	-20.3772	.01813	-39.5030	-1.2514	.0652	.2496
					CONSTANT	79.9563		57.3482	102.5645		

Table 31. Site Preparation, Cost per Acre Model Summary*

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
53.98	31.16	64	73.53	17.0027	OBS 1	-27.2071	.34729	-36.6747	-17.7395	.4219	.4978
					Item 80		.09288			1.4063	3.3320
					Item 92	-.0048	.08039	-.0089	-.0006	4124.2969	1106.3011
					MET 14	13.4199	.06443	2.3612	24.4787	.2344	.4270
					SLOP 2	17.7957	.05339	8.2957	27.2957	.3125	.4672
					Item 40	.0251	.02617	.0157	.0345	440.5000	534.3017
					Item 77	-.0787	.03843	-.1081	-.0493	189.4375	169.7831
					MET 18	-23.2247	.04385	-36.8655	-9.5839	.1406	.3504
					-Item 80		-.01148			1.4063	3.3320
					CONSTANT	83.5593		64.7656	102.3530		

*Data base before edit.

(EQUIP 1) was the only dummy variable of significance from the equipment-type category and always had a positive coefficient associated with it. Since the dependent variable is a measure of time, one would expect a positive relationship between the use of hand tools and man-hours.

Not only did complete site preparation with dozer and blade (MET 14) cost more, as discussed above, but it also took more time as did scarification (MET 110). Scale economics also appear to exist for man-hours as the number of acres treated has a negative coefficient associated with it in most cases. This is possibly due to employees becoming more familiar with the operational characteristics of the job as more acres are treated. Jobs completed between the months of December and February (SEA 1) had a tremendous impact on the amount of variation removed since 9 runs had at least 60% of the total variation in man-hours accounted for by SEA 1, always resulting in a positive adjustment. Variables describing ground cover characteristics (VEG) were also important to the reduction of standard error and variation. No definitive patterns were apparent, however, since their resulting sign seemed to be more dependent on the other variables in the equation than on the expected logical consequences.

Tables 32 and 33 show the recommended total and per acre man-hours models, respectively. Their results support the general conclusions made concerning the determination of man-hours. The large positive coefficient associated with SEA 1 suggests that site preparation should be avoided between December and February because of the increased time required to complete the operation. Since the per acre model only includes dummy variables, the average time required should approach the constant if none of the variables are true. That is, if a method other than scarification (MET 11) or complete site preparation with dozer and blade

(MET 14) is employed and non-powered hand tools are not required and the ground cover be described by VEG 1 or VEG 8 and the job is performed on another forest than the Siskiyou (USFS 9), then the constant value of 1.28 should represent the average per acre time required to complete site preparation. The equation has no practical significance if VEG 1 and/or VEG 8 are the only variables that are true. Unfortunately all models developed to predict per acre man-hours requirements for site preparation suffer from similar limitations as illustrated by the "best" model developed using the unedited data base (Table 34). Therefore, the total man-hours model (Table 32) may be more appropriate since it includes three continuous variables that would allow application to a number of situations. Both recommended models represent a 68% improvement in predictive accuracy and apply to jobs of less than 300 acres.

Intuitively, one would expect models designed to explain equipment hour requirements to be very similar to those designed for man-hour projections. However, for site preparation, results from 10 runs indicated equipment hour requirements were generally sensitive to fewer factors than man-hour requirements. National forest designations are responsible for the removal of significant amounts of variation as illustrated in the per acre model (Table 35) where approximately 15% of the total variation was explained by three USFS designations. Non-powered (EQUIP 1) and powered hand tools (EQUIP 2) were the only dummy variables from the equipment-type category of significance; each having a positive influence on equipment hour requirements. Whip felling (MET 18) and scarification (MET 110) had positive effects on the dependent variable in addition to being the only significant variables from the method category. Like the man-hours model, jobs completed between the months of December and February continued to account for a sub-

stantial portion of the total variation in equipment hour requirements. Variables describing ground cover (VEG) were also very important to the reduction in variation. Unlike man-hours, however, they always had positive coefficients associated with them which made their interpretation more meaningful.

With the exception of elevation (Item 92), the per acre model (Table 35) includes only dummy variables. Since the confidence interval for the constant includes zero and the constant itself is not significant at the 5% probability level, the model will be of little use when none of the variables are true. Therefore, the "best" model developed using the unedited data is presented in Table 36. It has some practical significance because man-hours required (Item 40) is included. The total equipment hour requirement model (Table 37) is also of little value since the standard error of the estimate is so high and the model accounts for so little variation. Furthermore, only a 13% improvement in accuracy is obtained using the total model while a 46% improvement is obtained for the per acre estimate.

National forest designations were important to the reduction of error in models designed to predict USFS man-hours (Tables 38-39). Cost, man-hours and equipment hours requirements were also important indicators of the size of the job and thus, USFS personnel contributions necessary for direct preparation, supervision, and inspection. Five of the seven methods used to complete site preparation were significant, contributing positively to USFS man-hour requirements. Ground cover descriptions (VEG) were also important but their respective signs were not consistent. Both, the total and per acre models include enough continuous elements to allow their application to a number of situations as long as they don't

exceed 330 acres. Predictive accuracy is improved by 68% for the per acre model and 80% for the total estimate.

Attempts at modeling USFS cost were not successful. This was expected, however, since very little expendable equipment and/or material was provided by the USFS to complete site preparation operations.

Of the seven runs made to develop models capable of predicting the total number of days and days per acre (Table 40 and 41), respectively), the two presented are the only ones which provided any useful information with regards to the variation observed. Both models contain posteriori variables which contribute to the explanation of variation in the sample but are, consequently, of little value as prediction equations. National forest designations (USFS) are again responsible for reducing the standard error of the estimates. Experience and size of contracting firm also appears to reduce the number of days required (Item 21 and 23). Time extensions (DEGREE 1) and quality of the work completed (QUAL 1) serve to increase the number of days required. Number of man-hours required (Item 40) acts as an indicator of the size of the job in the total model. The use of powered (EQUIP 1) and non-powered hand tools (EQUIP 2) decreases the time required while small farm type tractors increase the time. Scarification (MET 110) requires more time than does windrowing (MET 112). Accessibility problems don't appear to have any effect as Items 78 through 80 were never significant. Jobs completed between the months of December and February (SEA 1) required more time than the other seasons supporting previous findings. Slopes of degrees greater than 16-30% (SLOP 2) also required more time. Ground cover descriptions were important to the elimination of variation as shown by the per acre model where 59% of the variation was accounted for by jobs where 4"-10" dbh, light density pole timber (VEG 7) was a problem. Most of the var-

Table 32. Site Preparation, Total Man-Hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
409.3830	478.5050	47	91.08	157.2620	SEA 1	1709.8885	.70891	1404.3443	2015.4327	.2040	.0426
					Item 77	1.1098	.04548	.7752	1.4443	159.1416	166.2872
					Item 80	-21.7775	.04446	-36.7761	-6.7788	3.6228	1.4894
					MET 110	237.6825	.03515	101.8182	373.5468	.3599	.1489
					EQUIP 1	455.6971	.02670	239.9680	671.4262	.2471	.0638
					USFS 9	414.6650	.02302	200.5596	628.7702	.3117	.1064
					VEG 8	-362.0133	.01362	-641.8652	-82.1614	.2040	.0426
					Item 78	-1.5188	.01344	-2.8041	-.2334	35.0802	46.3404
					CONSTANT	161.1438		67.2425	255.0450		

Table 33. Site Preparation, Man-Hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
3.78	5.54	47	91.52	1.7513	SEA	15.6927	.64889	12.2881	19.0973	.0426	.2040
					MET 110	3.7922	.07978	2.2361	5.3483	.1489	.3599
					EQUIP 1	10.1830	.05917	7.5057	12.8603	.0638	.2471
					USFS 9	7.7337	.04469	5.3517	10.1158	.1064	.3117
					VEG 8	-8.2434	.04909	-11.4388	-5.0479	.0426	.2040
					VEG 1	-3.9285	.01986	-6.8379	-1.0190	.0426	.2040
					MET 14	1.7933	.01372	.3494	3.2371	.1702	.3799
					CONSTANT	1.2843		.5658	2.0027		

Table 34. Site Preparation, Man-Hours per Acre Model Summary*

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
3.2456	5.0454	45	97.44	.8927	SEA 1	15.4565	.86099	13.2122	17.7008	.0444	.2084
					VEG 7	8.4938	.04942	6.6457	10.3420	.0667	.2523
					MET 14	1.7091	.03166	1.0096	2.4086	.2667	.4472
					Item 79	-.0173	.01121	-.0346	-.00003	30.0222	17.4571
					VEG 9	3.3483	.00661	1.4268	5.2697	.0222	.1491
					OBS 6		.00482				
					VEG 4	1.2313	.00424	.3516	2.1110	.1333	.3438
					EQUIP 1	2.5123	.00398	.5908	4.4338	.0222	.1491
					MET 110	1.5344	.00293	.5334	2.5354	.0889	.2878
					-OBS 6		-.00148				
					CONSTANT	1.6248		.9525	2.2972		

*Utilizes data base prior to final edit.

Table 35. Site Preparation, Equipment Hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
3.6470	5.6037	47	77.22	3.0234	SEA 1	11.6595	.2341	6.4179	16.9011	.2040	.0426
					VEG 1	7.3111	.0571	3.7802	10.8421	.3117	.1064
					EQUIP 1		.0847				
					MET 110	11.3638	.0621	8.0054	14.7223	.3599	.1489
					EQUIP 2	4.9886	.0487	2.5729	7.4043	.4522	.2766
					FTYPE 12	11.1614	.0492	-14.8505	-7.4723	.4408	.2553
					SLOP 2	-4.9771	.0456	-7.1713	-2.7829	.4623	.2979
					-EQUIP 1		.0389				
					USFS 6	-16.1331	.0778	-23.6856	-8.5806	.1459	.0213
					Item 92	.0013	.0627	.00036	.0022	1195.0521	4127.7660
					USFS 1	6.7798	.0399	2.3618	11.1979	.3373	.1277
					USFS 15	3.7794	.0314	.3375	7.2213	.3373	.1277
					CONSTANT	-2.7581*		-6.7026	1.1863		

*Not significant at 5 percent probability level.

Table 36, Site Preparation, Equipment Hours per Acre Model Summary*

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
2.9229	3.9025	39	95.67	.8589	VEG 7	6.4756	.8099	5.0903	7.8627	.3074	.1026
					Item 40	.0038	.9163	.0030	.0046	526.9733	459.8462
					Item 77	-.0047	.9468	-.0069	-.0025	143.1044	184.6154
					VEG 9	2.4690	.9567	.6692	4.2686	.1601	.0256
					CONSTANT	1.3017		.7763	1.8271		

*Utilizes data base prior to final edit.

Table 37. Site Preparation, Total Equipment Hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
411.1915	581.7954	47	28.20	504.0747	SEA 1	1304.8500	.1896	568.7635	2040.9365	.2040	.0426
					VEG 1	568.8500	.0924	86.9683	1050.7317	.3117	.1064
					CONSTANT	295.1500		134.5228	455.7772		

Table 38. Site Preparation, Total USFS Man-Hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
133.09	181.80	46	96.56	37.2059	Item 19	.0079	.53984	.00513	.0107	7222.7609	6179.9600
					USFS 9	180.4527	.21786	113.4689	247.4365	.0870	.2849
					ACSQU	.0014	.14027	.0011	.0016	53636.0652	127632.9101
					Item 77	-.6253	.02129	-.8367	-.4140	168.8478	160.2649
					Item 76	6.7459	.01068	4.2731	9.2187	2.3478	6.5565
					Item 40	.0943	.01956	.0570	.1316	407.8478	483.6755
					OBS 10	-58.3798	.00761	-96.3843	-20.3752	.1087	.3147
					USFS 13	-69.3236	.00846	-115.9246	-22.7226	.0652	.2496
					CONSTANT	49.0877		21.1823	76.9830		

Table 39. Site Preparation, USFS Man-Hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Interval Upper	Variable Means	Variable Std. Dev.
1.10	1.29	46	91.68	.4058	USFS 9	4.0003	.67878	3.5153	4.4852	.0870	.2849
					ARECIP	22.2918	.09990	9.4853	35.0983	.0115	.0106
					MET 14	.6463	.04673	.2750	1.0167	.1739	.3832
					VEG 8	-1.4299	.03764	-2.0682	-.7917	.0435	.2062
					FTYPE 11	.5369	.03274	.2557	.8181	.5217	.5050
					MET 110	.4241	.01204	.0694	.7789	.1522	.3632
					OBS 5	.6530	.00893	-.0015	1.3076	.0435	.2062
					CONSTANT	.0683		-.1520	.2886		

Table 40. Site Preparation, Total Days Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
36.17	33.26	29	95.75	7.7344	SEA 1		.63003			.0690	.2579
					Item 21	-.8241	.08339	-.9678	-.6805	10.4828	36.6817
					USFS 14	69.1631	.07428	52.3500	85.9763	.0345	.1857
					Item 40	.0909	.09025	.0815	.1002	451.7586	567.6428
					EQUIP 1	-57.5351	.04611	-74.6814	-40.3887	.0345	.1857
					-SEA 1		-.01175			.0690	.2579
					EQUIP 3	18.6966	.02551	6.8110	30.5823	.0690	.2579
					USFS 13	-15.6562	.01971	-25.8173	-5.4950	.1034	.3099
					CONSTANT	3.6889		-.7931	8.1710		

Table 41. Site Preparation, Days per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
.37	.48	29	99.87	.0261	VEG 7	.8739	.58662	.7983	.9496	.1379	.3509
					SEA 1	1.6083	.07738	1.5276	1.6890	.0690	.2579
					Item 21	-.0088	.22752	-.0092	-.0084	10.4828	36.6817
					MET 110	.4392	.05709	.3974	.4809	.1379	.3509
					SLOP 2	.1801	.01787	.1350	.2252	.1724	.3844
					USFS 13	-.1341	.00848	-.1782	-.0900	.1034	.3099
					QUAL 1	.1010	.00609	.0654	.1366	.8276	.3844
					VEG 5	.1510	.00432	.1113	.1908	.1379	.3509
					SEA 3	.0990	.00382	.0664	.1316	.4138	.5012
					DEGREE 1	.1797	.00214	.1235	.2360	.0690	.2579
					USFS 14	.1267	.00231	.0275	.2259	.0345	.1857
					MET 112	-.1288	.00155	-.1829	-.0747	.0690	.2579
					EQUIP 2	-.0840	.00109	-.1234	-.0447	.2579	.4559
					Item 23	-.0026	.00096	-.0049	-.0002	8.0345	6.3442
					SEA 2	.0940	.00072	.0388	.1492	.1379	.3509
					VEG 6	-.0806	.00077	-.1457	-.0156	.0690	.2579
					CONSTANT	.0381		-.0118	.0879		

iables in the per acre model contribute so little to the explanation of variation, it would be advisable to drop those which enter after SLOP 2. The number of employees working for the contractor (Item 21) should also be dropped and the model run again to obtain one more useful for predictions.

Reforestation Model Development Results

Models developed for reforestation, were the most interesting and perhaps the most indicative of true population parameters and relationships because of the number of observations available (147 after final edit). On the average, more regression runs per dependent variable were made within this category because of a larger number of confounding elements.

The following general observations are based on a total of 21 runs made to investigate the influence of the postulated variables (Table 9) on total and per acre costs of reforestation. National forest designations (USFS) consistently reduced variation and the standard error of the estimate. As expected, costs were higher for those contracts awarded in 1977 (Item 14), than in 1976 while controlling for confounding effects. Those contracts awarded in the last quarter (Item 13), however, always had a negative effect on costs which was not anticipated. A probable explanation of the phenomenon in Item 13 was only significant after Item 14 had already entered the equation. Therefore its coefficient may represent an adjustment on the total change previously attributed to the year the contract was awarded. In combination, the two always had a positive net effect. An inverse relationship exists between increased numbers of bids received and costs as postulated. The number of years a contractor has been in the business of performing silvicultural operations

(Item 23) correlated positively with cost in every case where it was a significant variable. Jobs requiring time extensions (DEGREE 1) were always more expensive while jobs completing less than all terms of the contract (DEGREE 2) were consistently cheaper. Furthermore, jobs judged as being less than excellent quality (QUAL 1 & 2) were less expensive. Man-hour and equipment hour requirements, Items 40 and 46, respectively, were not as important to cost determination as expected but were positively related when either entered the equation. Type of equipment used was an important variable in controlling for confounding effects. Specifically, powered hand tools (EQUIP 2), persumably augers, was the only significant dummy variable from the equipment-type category to enter the equations. Its coefficient consistently indicated a positive influence on costs. The method employed was also a significant controlling variable. Hand planting (MET 119) and auger and hand (MET 122) were the only significant dummy variables from the method category, with hand planting being negatively correlated with cost while auger and hand planting always had a positive effect on cost. Variables dealing with multiple areas (Items 74 and 76) were always negatively related to costs.

Scale economics were evident for per acre models which has acres treated (Item 77) associated with a negative coefficient. Accessibility factors did not appear to substantially impact costs since travel time (Item 78 and 80) was only significant in three models. A positive relationship between the number of trees planted per acre and cost is evident as was expected from reviews of previous studies. True firs (SPEC 4) were identified as being most expensive to plant while lodgepole (SPEC 3) and ponderosa (SPEC 2) pine were the least expensive. Areas with slopes greater than 16-30% were more expensive to plant than level areas as one would expect. Dummy variables describing impediments to progress were

important for controlling confounding effects. Interpretation of their coefficients is difficult, however, as OBS 1, no impediment, OBS 2, land compacted soils, and OBS 8, fragile soils were always positively correlated while OBS 4, large rocks and/or stumps, OBS 5, dense brush, and OBS 12, inclement weather were always negatively correlated with cost. Ground cover descriptions are also difficult to interpret since VEG 1 and 4 were always positively correlated while VEG 2 had a negative coefficient associated with it. Forest type was also an important variable. Areas characterized by ponderosa pine and spruce-fir timber types were more expensive to plant than the Douglas-fir timber type.

In summarizing the per acre models, the single most important variable in terms of frequency of significance and variation reduction was Item 14, year of award. Approximately 17% of the total variation was accounted for by this variable. On the average, it's coefficient added $16.00 per acre to contracts awarded in '77. Hand planting was concidered the second most important variable, accounting for an average of 15% of the total variation and reducing per acre costs by an average of $20.00. Number of bids and multiple areas also consistently reduced per acre costs. In general, all models were sensitive to site characteristics.

Total models were effected by essentially two variables, acres treated (Item 77) and acres squared (ACSQU). On the average, Item 77 accounted for 80% of the total variation and added $49.00 per acre to the constant. Acres squared only accounted for an additional 6% of the total variation, on the average.

Many of these same relationships discussed here are illustrated in the recommended total and per acre models (Tables 23 and 28, respectively). Per acre estimates are improved by 40% while the total model accounts for a 66% improvement over average estimates. The per acre model is appro-

priate for jobs of less than 385 acres and the total model applies to jobs between 19 and 267 acres. If none of the dummy variables in the per acre model apply to the specific situation for which an estimate is desired, the model developed using 105 cases (Table 43) is suggested.

General observations concerning the number of man-hours required to complete planting activities are based on 22 regression runs. National forest designations (USFS) are again important to the reduction in variation and standard error of the estimate. Variables describing the contracting firms size and experience (Items 20 through 23) were negatively correlated with the dependent variable. Equipment hours required (Item 46) correlated strongly with man-hours required as one would expect. Hand planting (MET 119) always required less time than planting with augers (MET 121). An inverse relationship between the number of multiple areas (Item 74) and man-hours exists while the average distance between multiple areas (Item 76) acts to increase man-hour requirements. Scale economics appear to exist between the dependent variable and acres treated for the per acre models. The negative coefficient associated with acres squared and its reciprocal also support this observation. The number of seedlings planted per acre, quite naturally, has a positive effect on man-hour requirements. True firs (SPEC 4), Douglas-fir (SPEC 1), and ponderosa pine (SPEC 2) seem to require more time than lodgepole pine (SPEC 3) and sugar pine (SPEC 5) which consistently had negative coefficients. Dummy variables describing impediments to progress showed positive correlations with hard compacted soils (OBS 2), dense brush (OBS 5), and severe slopes (OBS 9) while negative coefficients were associated with no impediment (OBS 1) and down material (OBS 10). Ground cover descriptions (VEG 1 and VEG 4) also had positive effects on man-hour requirements.

Planting of true firs (SPEC 4) was by far the single most important variable to enter the equations. On the average, it accounted for 13% of the total variation and increased time by an average of 4 man-hours per acre. Dense brush (OBS 5) was the second most signficant variable as it accounted for an average of 8% of the total variation while increasing per acre man-hour requirements by 10. In general, all per acre models were sensitive to site characteristics, accessibility factors, and method and/or equipment used. Acres treated (Item 77) and acres squared (ASCQU) were the only truly significant variables in the total models.

Tables 42 and 43 show the recommended total and per acre models, respectively, for man-hours required to complete planting operations. These models illustrate a number of the general observations made above concerning man-hour requirements. Both models include enough continuous variable to allow their application to a number of situations. The per acre model is appropriate for jobs of less than 300 acres and the total model for jobs of less than 245 acres. The total model could use some revisions, however, as those variables contributing less than 2% to explained variation should be dropped as should the constant since its confidence interval includes zero. A 35% improvement in accuracy is possible with the per acre model and a 64% improvement with the total estimate.

A total of 19 runs yielded the following observations concerning equipment hours required to complete planting operations. Unlike the previous models discussed, national forest designations (USFS) actually had detrimental effects on variation and standard error of the estimate. An inverse relationship was evident between the dependent variable and the amount of equipment owned by the contractor (Item 20) and the percentage of time the contractor spent performing silvicultural operations (Item 22)

Conversely, the number of employees (Item 21) and the number of years the contractor had been in business (Item 23) had positive effects on equipment hours. Powered hand tools (EQUIP 2) was the only significant dummy variable from the equipment-type category and always exercised a negative effect on equipment hours required. As expected, a strong positive correlation between the dependent variable and man-hours required (Item 40) was evident. Auger and hand planting appears to increase equipment hours relative to the other methods included in the sample. Increasing numbers of multiple areas (Item 74) acted to decrease equipment hours as did increases in acreage (Item 77) for per acre models. Measures of accessibility (Items 79 and 80) showed positive effects on the number of equipment hours required. Both the number of seedlings planted per acre (Item 85) and the number of months since site preparation was completed had positive effects on the dependent variable. The planting of true firs (SPEC 4) and ponderosa pine (SPEC 2) required more equipment hours than did the planting of sugar pine (SPEC 5). Hard compacted soils (OBS 2), dense brush (OBS 5), and fragile soils (OBS 8) had positive effects on the number of equipment hours required while no impediment (OBS 1), down material (OBS 10) and grass (OBS 13) had negative effects. Ground cover descriptions (VEG 2 and VEG 3) always had positive influences. Coefficients associated with acreage transformations were generally indeterminate as no clear-cut pattern was established. The planting of true firs and the use of powered hand tools were the two most influential variables accounting, on the average, for 14 and 11% of the total variation, respectively.

The recommended total and per acre equipment requirement models (Tables 44 and 45, respectively) support these general observations. The

total model should be run again to force the intercept through zero since the constant is not significant. Nevertheless, the model is applicable to many situations because of Items 77 and 86. It is appropriate for jobs between 19 and 267 acres. Use of the per acre model requires the not unreasonable assumption that all items of the contract will be completed as specified, therefore DEGREE 2 will have a value of zero. The total and per acre models represent 45 to 48% improvements, respectively, in predictive accuracy.

General observations concerning the influential factors for USFS man-hours required to prepare, supervise, and inspect reforestation operations are based on the results of 10 regression runs. The effect of national forest designations (USFS) was indeterminate as some models did benefit while others suffered from their inclusion. Apparently, there was less supervision needed for contractors having a large number of employees (Item 21) and for those who had been in the silviculture business for a number of years (Item 23) as both had a negative impact on the dependent variable. Jobs judged as being of less than excellent quality (QUAL 1 and QUAL 2) required more USFS time. Hand planting (MET 119) received less attention from USFS personnel than auger and hand planting operations (MET 121). The number of multiple areas (Item 74) and the average distance between them (Item 76) served to increase USFS time. Economies of scale also appear to be in effect since fewer man-hours are spent on a per acre basis for large jobs than small ones. Signs associated with variables describing impediments were consistent but their interpretation is difficult. For example, no impediment (OBS 1), large rocks and/or stumps (OBS 4), and several slopes (OBS 9) had a negative effect on the number of USFS man-hours while hard compacted soils (OBS 2), dense brush (OBS 5), down material (OBS 10), and inclement

weather (OBS 12) required more time as indicated by their positive coefficients. The negative coefficient associated with VEG 7, the only significant dummy variable from the ground cover category, was also difficult to interpret, since alone its literal interpretation would suggest an unwillingness by USFS personnel to spend much time in an area characterized by such cover. On the other hand, the positive coefficient associated with down material (OBS 10) suggests more time is spent in areas having those characteristics. The reciprocal of acres was, by far, the most significant variable for per acre models as it accounted for an average of 62% of the total variation. Acres treated were, again, the single most important variable in total models.

The total and per acre models (Tables 46 and 47, respectively) include most of the significant factors discussed here. The user must assume that the quality of the work to be performed will be excellent, thus eliminating QUAL 2 from the per acre model. The total model should be run again to force the intercept through zero since the constant is not significant at the 5% probability level. Predictive accuracy is improved by 51% using the per acre model but only by 26% for the total. Both models apply to jobs of less than 380 acres but suggest using per acre model where possible as the total model is considered poor.

Of the 9 runs made to develop models designed to predict USFS costs incurred for materials and/or equipment provided to the contractor, the total and per acre models presented (Tables 48 and 49, respectively) are the most indicative of the patterns and kinds observed in the other attempts. As many of the other models have shown, national forest designations (USFS) are important to the reduction of variation and the standard error of the estimate. Unlike the other models, however, the

USFS cost models investigated here, frequently have the east side/west side (Item 10) factor entering the equation with a negative coefficient. indicating west side expenditures are less than east side. Since USFS cost is suppose to represent the value of materials and/or equipment provided for the contractor, one would expect a high correlation between the list of items provided and the cost. Fortunately, the list (FSMAT) is represented in the per acre model. On the average, the contribution of seedlings (FSMAT 5) adds $8.46 to the per acre cost incurred by the USFS. Scale economies also act to reduce costs in the per acre model as shown by the negative coefficient associated with acres treated and acres squared in the total model. The significance of the number of miles to the work site (Item 79) in the total model may be due to transportation costs required for moving the planting stock. Stocking density as measured by Item 85 is not significant in the recommended models but is accounted for in other runs as is the number of months since site preparation was completed (Item 86) possibly requiring older and thus more expensive planting stock for areas where competition may have the lead. Douglas-fir seedlings also appear to be more expensive than the other candidates since a positive coefficient was always included with its entrance into other equations. Both recommended models are applicable to a wide range of situations but the constant in the total model should be removed as it is not significant at the 5% probability level. Only a 50% improvement in accuracy is provided by the per acre model and 34% by the total. Both models are appropriate for jobs of less than 385 acres.

Results from attempts at developing models designed to predict the per acre number of days (Table 50) required to complete planting operations

Table 42. Reforestation, Total Man-Hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Interval Upper	Variable Means	Variable Std. Dev.
713.87	724.14	83	88.68	118.6768	Item 77	4.7225	.64221	4.1915	5.2535	125.7349	258.2498
					Item 86	48.5278	.06094	35.4432	61.6123	8.3614	4.4601
					USFS 1	1951.9926	.07019	1398.3363	2505.6489	.0120	.1098
					USFS 4		.02399			.0482	.2155
					ACSQU		.01682			29723.7590	51198.8315
					USFS 7	-659.6980	.01408	-887.7729	-431.6231	.0843	.2796
					USFS 15	-384.3778	.01752	-549.7469	-219.0086	.4578	.5012
					Item 80		.00845			2.4699	3.5177
					ACSQU		-.00517			----	
					Item 74	-32.9672	.01239	-47.1842	-18.7503	6.5422	4.8572
					OBS 1	-301.3877	.01548	-429.1550	-173.6205	.6265	.4867
					USFS 4		-.00552			----	
					Item 80		-.00535			----	
					Item 76	11.4899	.01178	1.9666	21.0132	12.0120	8.4889
					SEA 2	184.8325	.00896	31.5464	338.1186	.7952	.4060
					CONSTANT	41.9275		-155.1827	239.0376		

Table 43. Reforestation, Man-Hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
6.29	3.37	105	61.99	.2666	SPEC 4		.09287			.0762	2.1989
					OBS 5	9.8142	.08545	5.3918	14.2365	.0095	.0976
					MET 119	-2.4285	.07804	-3.5857	-1.2712	.7524	.4337
					ARECIP	64.6083	.05470	40.8440	88.3726	.0297	.0567
					Item 46	.0034	.05054	.0025	.0044	637.1143	655.4120
					A2RECIP	-141.6619	.09487	-223.5833	-59.7406	.0041	.0160
					ACSQU	-.0002	.04106	.0003	- .0001	35655.8800	55461.8680
					SPEC 3	-4.2972	.02960	-7.0310	1.5635	.0286	.1674
					SEA 3	4.7594	.02745	2.5051	7.0137	.0667	.2506
					SPEC 4		-.01699			---	
					OBS 10	-2.9033	.02854	-5.3105	-.4961	.0571	.2332
					EQUIP 2	1.6218	.02650	.5036	2.7399	.3048	.4625
					SPEC 5	-3.8831	.02725	-6.8694	-.8968	.0476	.2140
					CONSTANT	4.9909		3.6635	6.3183		

Table 44. Reforestation, Total Equipment Hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
637.1143	655.4120	105	71.26	360.1576	Item 77	3.5225	.5290	2.9476	4.0975	142.7810	124.1624
					OBS 2	751.3760	.0688	182.3577	1320.3942	.0190	.1373
					EQUIP 2	-356.3715	.0553	-509.9241	-202.8190	.3048	.4625
					Item 86	29.4753	.0386	13.2992	45.6514	7.5048	4.6886
					USFS 4	470.5151	.0208	122.1147	818.9154	.0476	.2140
					CONSTANT*	-15.1500		-173.5922	143.2923		

*Not significant at 5 percent probability level.

Table 45. Reforestation, Equipment Hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
5.19	3.62	105	76.70	1.8678	EQUIP 2	-4.0187	.14627	-4.8871	-3.1503	.3048	.4625
					SPEC 4	1.7771	.11842	.1995	3.3547	.0762	.2666
					OBS 5	9.1957	.07773	5.1611	13.2303	.0095	.0976
					Item 77	-.0527	.05385	-.0657	-.0408	142.7810	124.1624
					Item 40	.0040	.14818	.0031	.0049	799.0000	742.2008
					ACSQU	.00007	.05706	.00005	.00009	35655.8857	55461.8684
					DEGREE 2	5.1964	.03680	3.2047	7.1881	.0476	.2140
					OBS 13	-6.1020	.02564	-9.2764	-2.9276	.0190	.1373
					Item 74	-.2340	.03544	-.3230	-.1451	6.3048	4.7254
					Item 86	.1495	.01881	.0657	.2333	7.5048	4.6886
					Item 85	.0046	.01465	.0018	.0074	486.3048	160.5008
					SPEC 2	1.4011	.01699	.4824	2.3198	.2952	.4583
					OBS 9	2.0473	.01712	.4743	3.6203	.0762	.2666
					CONSTANT	5.3839		3.5077	7.2602		

Table 46. Reforestation, USFS Man-Hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
168.22	257.68	130	47.91	190.4569	Item 77	.5935	.28435	.4241	.7628	183.6769	199.8498
					OBS 12	398.3140	.07703	221.3066	575.3214	.0462	.2106
					USFS 11	300.7243	.03733	126.4078	475.0408	.0385	.1931
					USFS 7	189.9335	.04086	70.3386	309.5283	.0923	.2906
					Item 76	4.4485	.02133	.4066	8.4095	9.9692	8.4044
					USFS 10	-435.8415	.01823	-851.6855	-19.9975	.0077	.0877
					CONSTANT*	-29.2688		-92.4697	33.4321		

*Not significant at 5 percent probability

Table 47. Reforestation, USFS Man-Hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
1.43	1.55	130	77.22	.7622	ARECIP	37.8490	.62316	30.9239	44.7740	.0268	.0524
					OBS 1	-1.0317	.04255	-1.3923	-.6712	.5769	.4960
					VEG 7	-1.9023	.02872	-2.6615	-1.1432	.0385	.1931
					A2RECIP	-51.6799	.02315	-76.0993	-27.2605	.0034	.0144
					QUAL 2	.5246	.01358	.1960	.8533	.2462	.4324
					MET 121	.6054	.01508	.2031	1.0078	.1462	.3546
					OBS 4	-.9002	.01628	-1.4009	-.3994	.1231	.3298
					OBS 9	-.5780	.00968	-1.0827	-.0733	.1077	.3112
					CONSTANT	1.2217		.9056	1.5378		

Table 48. Reforestation, Total USFS Cost Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
2998.73	2554.90	129	64.74	1566.9581	Item 77	21.6711	.20824	18.3394	25.0028	184.6589	200.3138
					ACSQU	-.0158	.25141	-.0188	-.0127	23913.4806	202233.2527
					USFS 12	3855.6263	.04027	2715.7469	4995.5057	.1163	.3218
					USFS 4	4454.0114	.02344	2841.2923	6066.7305	.0388	.1938
					Item 85		.02296				
					Item 79	18.5669	.01933	3.1415	33.9923	33.3643	18.7845
					USFS 8	3269.6507	.01622	2105.1864	4434.1149	.1173	.3558
					Item 10	-2847.1387	.04504	-3805.0241	-1889.2533	.5271	.5012
					USFS 7	2405.4359	.02608	1195.4114	3615.4605	.0930	.2916
					-Items 85		-.00564				
					CONSTANT*	-282.1671		-1036.3072	471.9731		

*Not significant at 5 percent probability

Table 49. Reforestation, USFS Cost per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Interval Upper	Variable Means	Variable Std. Dev.
21.79	10.75	129	53.76	7.4862	Item 77	-.0229	.23040	-.0296	-.0161	184.6589	200.3138
					USFS 8	13.6074	.13862	9.7928	17.4219	.1473	.3558
					USFS 12	9.0734	.06144	4.9020	13.2448	.1163	.3218
					USFS 5	21.3842	.05943	10.7495	32.0189	.0155	.1240
					USFS 4	9.2682	.02908	2.4447	16.0917	.0388	.1938
					FSMAT 5	8.4636	.01859	.8974	16.0297	.9690	.1740
					CONSTANT	14.0642		6.5350	21.5933		

Table 50. Reforestation, Days per Acre Model Summary*

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
.0848	.0905	147	44.37	.0687	USFS 5	.3115	.25603	.2411	.3819	.0340	.1819
					Item 77	-.0002	.08776	-.0003	-.0001	363.4830	366.6855
					ACSQU	.000000001	.04520	.00000004	.0000001	265663.4558	267205.9712
					Item 76	-.0026	.03102	-.0043	-.0010	7.5578	7.9010
					OBS 1	-.0297	.02367	-.0537	-.0057	.5966	.5017
					CONSTANT	.1588		.1303	.1874		

*Utilizes data base prior to final edit.

were not very encouraging. A total of five runs indicated the dependent variable was sensitive to only seven factors, all of which are represented in the recommended model. Note that this model was developed prior to the final edit. Coefficient signs agree with those occurring in other models. Acres squared is of questionable importance because of its extremely small coefficient. It did, however, account for over 4% of the total variation. The Ochoco National Forest consistently accounted for the majority of the variation, followed by acres treated (Item 77) and average distance between multiple areas (Item 76). The model applies to jobs of less than 730 acres but only provides a 24% improvement in predictive accuracy.

TSI Model Development Results

A total of 105 cases were retained in the data base for TSI (precommercial thinning) operations after the final edit. In general, fewer runs were made for each dependent variable in this category than in reforestation on site preparation. USFS cost models were not developed since, essentially, no expendable materials and/or equipment was provided to correlate the costs with, or least not enough observations of such. Models designed to forecast the number of days required are not presented as too few runs were made to make any general observations nor suitable explanatory models.

General observations concerning the cost of precommercial thinning operations are the result of 14 regression runs. TSI cost models were influenced by both national forest designations (USFS) and east side/west side designations (Item 10). National forest designations were responsible for most of the improvement in predictive accuracy. Several models included positive adjustment for the year of award (Item 14),

but not the recommended models. Completion of less than all items in the contract resulted in less cost i.e., less money paid to the contractor. As expected, man-hour (Item 40) and equipment hour (Item 46) requirements had a positive effect on the dependent variable. Powered hand tools (EQUIP 2) presumably chain saws, was positively correlated with cost and represented the only significant dummy variable from the equipment-type category. Acres treated (Item 77) and number of multiple areas (Item 74) were both positively correlated with cost suggesting the absence of scale economies. Acres squared, however, did have a negative coefficient in all models in which it was significant. Measures of accessibility (Item 78 and Item 79) also served to increase costs as distances increased. The coefficients associated with the various degrees of slope were difficult to interpret, since slopes of less then 8% (SLOP 1) had negative coefficients as did slopes of 16-30% (SLOP 2) while the intermediate class, slopes of 9-15% (SLOP 2), had a positive coefficient. SLOP 3, however, occurs after SLOP 2 is already included in the model yielding a positive net adjustment. As seen in previous models, the interpretation of variables describing impediments to progress also pose problems in these models. Dense brush (OBS 5) and inclement weather (OBS 12) always contribute positively while large rocks and/or stumps (OBS 4), severe slopes (OBS 9), and down material (OBS 10) provide negative contributions to costs. Operations in the ponderosa pine timber type appear to be less expensive relative to operations in other forest types. Positive influences are associated with increases in the number of trees treated (Item 109) and increases in the average DBH of treated items (Item 110). The effect of groundcover descriptions is indeterminate since the pattern of

coefficient signs is not consistent. Tables 51 and 52 show the recommended total and per acre cost models, respectively. General observations made above are supported by the models. Use of either model as a means of prediction requires the assumption that all terms of the contract will be completed, thereby eliminating DEGREE 2. The total model will also have to be run again in order to force the intercept through zero. Variables entering the total model after SEA 1 should also be dropped as each contributes very little to the removal or explanation of total variation.

Both models are very good considering the improvement in predictive accuracy obtained. A 50% improvement occurs with the per acre model and a 75% improvement with the total model. Enough continuous variables are included in each to allow applications in many circumstances between 2 and 560 acres in size.

A total of 15 runs support the observations concerning man-hour requirements for precommercial thinning. Predictive accuracy of per acre models did not benefit from national forest designations nor was Item 10 of significance. A positive correlation between equipment hour requirements (Item 46) and man-hour requirements was evident though as postulated. Powered hand tools (EQUIP 2) also acted to increase man-hour requirements relative to large heavy machinery (EQUIP 6) which required less. Increases in the number of multiple areas (Item 74) and the distance between them (Item 76) had a negative impact on the dependent variables as did acres treated for per acre models. Acres squared and its reciprocal were also negatively correlated with man-hours required while the reciprocal of acres had a positive impact. No

No consistent trends were apparent for variables describing impediments to progress even though a representative from that category was frequently included in the final equations. Operations occurring in the ponderosa pine timber type (FTYPE 12) were generally less time consuming than those occurring in the Douglas-fir forest type. As in the previous cost model, the number of trees treated (Item 109) and their average DBH (Item 110) had positive impacts on the dependent variable.

Total and per acre models recommended for prediction man-hour requirements (Tables 53 and 54, respectively) are representative of the relationships discussed above. The per acre model includes several continuous variables which should allow its application in a number of circumstances. The total model, however, requires the removal of the constant term, QUAL 1, Item 74, and ACSQU because of the limited contribution. Both models apply to jobs of less than 550 acres. Total man-hour estimates are improved by 64% while per acre estimates improve by 31%.

Models designed to predict equipment hours required to complete precommercial thinning were developed through the analysis of 17 regression runs. The models were expected to be similar to the man-hour models discussed above since most TSI operations are labor intensive. Many similarities did exist, however, there were also some important differences. For one, national forest designations (USFS) did, on the average, improve predictive accuracy. The man-hour models identified the negative influence associated with large heavy machinery (EQUIP 6), but EQUIP 6 was the only significant variable from the equipment-type category to enter equipment hour models, exercising a negative influence. Jobs occurring between the months of March and May (SEA 2) experienced

increased time requirements possibly due to the large amount of precipitation normally occurring during those months. Marking (Item 88) served to decrease equipment hour requirements as did all of the descriptions of groundcover (VEG 1, VEG 5, and VEG 9). Acres squared was instrumental in removing large portions of variation in the total models.

Total and per acre models expressing equipment hour requirements (Tables 55 and 56, respectively) illustrate many of these relationships. The per acre model is considered barely acceptable as it only represents a 22% improvement in predictive accuracy. It does, however, apply to many situations since only two dummy variables are included. The total model represents a substantial improvement in predictive accuracy (59%). Both models apply to jobs of 550 acres or less.

The results of 9 regression runs showed USFS man-hour projections to be sensitive to only 11 of the variables postulated as having an influential impact. Recommended total and per acre models (Tables 57 and 58, respectively) are good examples of the significant variables and their respective trends. Season is the only category not represented that was important in other models. Both models indicate decreasing amounts of time spent for increasing acreage. Personnel from the Siskiyou National Forest appear to have spent a great deal more time monitoring TSI operations than did members of other forests. The per acre model does seem to indicate that Wenatchee personnel also spent more time than most others.

Acreage transformations were the most frequent variables to enter the models but the Siskiyou consistently accounted for the greatest

amount of variation. All models were sensitive to site characteristics but no general trends were observed.

Both models apply to jobs of 530 acres or less. A 69% improvement in predictive accuracy is obtained from the per acre model and a 47% improvement from the total.

Table 51. TSI, Total Cost Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Interval Upper	Variable Means	Variable Std. Dev.
9170.92	9047.95	71	94.65	2299.51	Item 77	26.7874	.72451	20.3137	33.2611	281.845	278.865
					Item 10		.09141			.3380	.4764
					EQUIP 2	3567.48	.03221	1514.29	5620.67	.9014	.3002
					SEA 1		.02198			.1408	.3503
					FTYPE 12	-5164.05	.01287	-6799.91	-3528.18	.5634	.4995
					DEGREE 2	-6085.25	.00913	-10852.70	-1317.77	.0141	.1187
					ACSQU	-.0095	.00694	-.0140	-.0049	156107	397769
					Item 74	662.258	.00978	438.639	885.878	3.3239	4.2954
					-SEA 1		-.00307			.1408	.3503
					Item 40	4.6435	.01031	2.8333	6.4537	1340.986	1512.963
					-Item 10		-.00424			.3380	.4764
					Item 46	3.9832	.01171	-5.7928	-2.1736	1133.127	1366.673
					SLOP 2	2222.03	.00931	687.25	3756.81	.2958	.4596
					OBS 10	-3774.34	.00549	-6603.79	-944.88	.0563	.2322
					SLOP 3	-1839.31	.00434	-3469.09	-209.53	.1690	.3774
					VEG 8	1963.62	.00380	27.2044	3900.04	.1408	.3503
					CONSTANT*	-1443.39		-3380.84	494.059		

* Not significant at 5 percent probability

Table 52. TSI, Cost per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
38.16	23.49	71	78.07	11.69	FTYPE 12	-10.5443	.40047	-19.9075	-1.1810	.5634	4995
					Item 109	.0122	.13685	.0094	.0151	1164.1831	1166.6463
					ARECIP	379.1306	.08726	197.2761	560.9852	.0099	.0163
					VEG 7	-32.7311	.04677	-50.2703	-15.1917	.0282	.1666
					DEGREE 2	-52.1408	.04338	-76.6964	-27.5852	.0141	.1187
					Item 10	15.9214	.03483	6.0927	25.7500	.3380	.4764
					SLOP 1	-9.9493	.01596	-18.2831	-1.6155	.1549	.3644
					SEA 2	-7.9979	.01515	-15.7236	-2.723	.1831	.3895
					CONSTANT	25.3580		15.1331	35.5829		

Table 53. TSI, Total Man-hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
1379.86	1547.01	77	88.01	556.2193	ITEM 77	4.9819	.7812	3.8691	6.0947	276.0909	277.0676
					EQUIP 6	-3833.7428	.0512	-5060.6463	-2606.8392	.0130	.01140
					QUAL 1	374.7437	.0113	94.1826	655.3048	.7013	.4607
					ITEM 74	-94.4978	.0091	-144.9065	-46.0891	3.2727	4.1411
						453.5668	.0161	170.9841	736.1495	.3636	.4842
					ACSQU	-.0011	.0119	-.0026	-.0018	151995.68	386430.58
					CONSTANT*	-221.7737		-544.2058	100.6584		

*Not significant at 5 percent probability level.

Table 54. TSI, Man-hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
5.87	4.18	77	55.73	2.8945	ARECIP	376.2708	.17276	239.8887	512,6529	.0099	.0157
					A2RECIP	-2994.68	.09306	-4479.49	-1509.86	.0003	.0014
					ITEM 46	.0025	.09343	.0016	.0035	1100.935	1323.836
					FTYPE 12	-2.3638	.06974	-3.7817	-.9460	.5195	.5029
					ACSQU	-.000005	.08101	-.000008	-.000002	151996.68	386430.58
					OBS 9	2.8520	.04729	.7719	4.9322	.1169	.3234
					CONSTANT	2.1138		.4286	3.7990		

Table . TSI, Total Equipment Hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
1100.9351	1323.8356	77	84.60	549.2337	ACSQU	.0024	.067473	.0016	.0032	151995.68	386430.52
					USFS 15		.04565			.2857	.4547
					EQUIP 6	-3582.4114	.03173	-4800.6400	-2364.1827	.0130	.1140
					USFS 6	-840.4697	.01877	-1452.4807	-228.4588	.0519	.2234
					ITEM 74	-97.1993	.01655	-146.0429	-48.3556	3.2727	4.1411
					-USFS 15		-.01044				
					ITEM 77	2.1018	.02952	.9435	3.2601	276.0909	277.0676
					OBS 5	-362.9862	.01085	-699.2163	-26.7561	.1948	.3986
					VEG 9	-1580.0551	.01264	-2470.0474	-690.0629	.0649	.2480
					USFS 8	1227.0107	.01599	305.3969	2148.6245	.0649	.2480
					CONSTANT	652.8891		385.2281	920.5500		

Table 56. TSI, Equipment Hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	95% Confidence Interval Upper	Variable Means	Variable Std. Dev.
4.8591	4.008	77	43.87	3.1065	SEA 2	3.0736	.07039	1.2846	4.8625	.1948	.3986
					QUAL 2	-2.9024	.06405	-4.9720	-.8329	.1429	.3522
					Item 77	-.0155	.07267	-.0211	-.0100	276.0909	277.0676
					Item 40	.0023	.19697	.0012	0033	1379.8571	1547.0123
					DEGREE 1	2.2043	.03463	.1043	4.3044	.1429	.3522
					CONSTANT	5.5260		4.3886	6.6633		

Table 57. TSI, Total USFS Man-hours Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
117.87	94.17	77	73.99	49,6886	USFS 9	285.3192	.4575	238.5054	332,1330	.0649	.2480
					ITEM 40	.0260	.1977	.0181	.0338	1379.8571	1547.0123
					OBS 5	55.5388	.0355	25.8907	85.1869	.1948	.3986
					VEG 5	40.8251	.0288	7.0637	74.5865	.1429	.3522
					ARECIP	-917.7614	.0204	-1693.0207	-142.5022	.0099	.0157
					CONSTANT	55.9044		33.8709	77.9379		

Table 58. TSI, USFS Man-hours per Acre Model Summary

Population Mean	Population Std. Dev.	Number of Cases	R-Square	Model Standard Error	Independent Variables	Coefficients	Change R-Square	95% Confidence Interval Lower	Upper	Variable Means	Variable Std. Dev.
.76	.88	77	91.34	.2729	USFS 9	2.9589	.7185	2.6940	3.2240	,0649	.2480
					ARECIP	49.6225	.0834	36.2350	63.0091	,0099	.0157
					USFS 14	1.4975	.0511	.9290	2.0661	.0130	.1140
					A2RECIP	-370.4614	.0285	-511.0201	-229.9026	.0003	.0014
					OBS 5	.2873	.0179	.1188	.4558	.1948	.3986
					USFS 8	-.3887	.0086	-.7093	-.0680	.0649	.2480
					VEG 5	.1898	.0052	.0041	.3756	.1429	.3522
					CONSTANT	.1274		.0162	.2388		

Conclusions and Recommendations

Three somewhat conflicting objectives were addressed in this study; two of which were the originally planned objectives and the other was a logical consequence, or requirement, for achievement of the original two. Specifically, multiple regression analysis was to be used to: 1) develop site-specific prediction equations relating influential variables to physical and monetary measures of cost, and 2) identify significant factors affecting costs. Both of these objectives require, as a starting point, a hypothesized model including a list of factors to be tested. Consequently, the third objective was formulated; determine the appropriateness of the hypothesized model i.e., determine whether or not the sample data supports the hypothesis.

The methodology employed in this study actually reverses the order of the three objectives. A model was postulated which included observable and/or controllable factors as well as elements which could not observed until after the fact. Regression analysis was then used to: 1) Examine the influence of the postulated variables i.e., identify variables which are related to the dependent variable and if possible, rate them in order of their importance, 2) Find the variable subset that yields the best linear prediction equation, 3) Construct an equation using a priori and/or predictable variables that gives the best prediction of the values of the dependent variable.

Because of the large number of factors suspected of influencing the cost variables, it was not feasible to make a regression run on each individual variable, though it was done for each continuous variable. As pointed out earlier, silviculture is extremely complex with many

elements influencing and confounding the results. Consequently, the results of runs on individual variables were generally poor. Elimination of confounding effects, primarily though the introduction of dummy variables, yielded much more satisfactory results. Significant factors were identified but, unfortunately, it was not possible to rate them according to their importance per se. Traditional methods of evaluating the impact of individual variables were not appropriate for the data collected in this study, which was plaqued by a relatively large number of missing values. Therefore, an approach was developed which would evaluate the trade-offs between changes in sample size and predictive accuracy resulting from the inclusion of individual or groups of variables.

By starting with the hypothesized model and working backwards, significant variables were identified and suitable prediction equations were developed. That is, an iterative approach was utilized that systematically eliminated posteriori factors and variables identified as "limiting" because of the large number of missing values associated with them. Each step (run) identified a variable subset which would produce the "best" linear prediction equation for the sample size involved. Eventually, a model was developed, capable of reasonably accurate predictions, based on the greatest number of observations possible as determined by acceptable standards of accuracy.

Since data deficiencies were the major reason for abandoning the accepted (traditional) evaluation methods, it seems appropriate to critique the collection procedures used in the study first. The length and complexity of the questionnaire is a deterrent to the collection of

accurate data when hard copy "answers" are not available requiring the respondent to think intently. Of course, the main reason hard copy answers are not readily available is because, up to now, no one has suggested that the information be recorded. Due to the findings of this study, some recommendations are in order:

1) Subjective and highly questionable estimates should be eliminated or improved. In particular, the quality assessment (Item 25) should be replaced by instructions informing the respondent to report only jobs that were acceptably completed i.e., no defaults. Items 21 and 23 dealing with contractor status should be retained if records of number of employees (ground personnel) and number of years in silviculture business can be maintained. Items 20 and 22 should be dropped completely as they rarely contributed to the models and are somewhat ambiguous.

   Estimates involving the physical input variables (e.g., man-hours, equipment hours, USFS man-hours, etc.) should be replaced with hard copy records. Day to day logs would yield much better measures of these items. On the ground communications between the forester and contractor concerning impediments to progress would improve the reliability of Item 93 (OBS) and Item 111 (VEG) which were so often important to cost determination. Items 79, 95, and 96 should be eliminated due to their subjective nature.

2) Multiple entries, such as the seven allowed for FS material, should be replaced by instructions informing respondent to

record the single most costly item (assuming it is based on hard copy data).

3) The respondent should be informed as to which items <u>must</u> contain information for a given practice. Absolutely no missing values should be allowed for the required items.

4) Obviously, some revisions in the multiple area instructions must be made. Reporting values for the entire contract and adding another item asking for the average size of the non-contiguous areas may be the easiest means of handling them, provided the contractor bids one value. If more than one bid value was awarded, the areas should be grouped according to their respective value and reported values divided accordingly.

After the improvements discussed above have been made, reporting forms and a more comprehensive, clear set of instructions should be distributed to all USFS district offices. A reporting form should be completed for every contract awarded as standard practice. Ideally, the information should be maintained on computer files to facilitate sampling schemes for future analysis.

With regard to future analyses, the very first task that should be undertaken involves the verification of the reliability of the models presented in this study. A residual analysis on each model would determine the appropriateness of the model to the data. If the analysis confirms the maintenance of assumptions concerning the error term (ε) for the classical normal linear regression model discussed in Chapter III, then the model is, indeed, appropriate. Examination of the per acre models is extremely important as there is a possibility of heteroshedasticity occurring.

Models with constants which are not significant at the 5 percent probability level should be run again to force the intercept through the origin. Those variables accounting for less than 2 percent of the total variation may be dropped at the users discretion. The decision should be based on the improvement in calculations which might be realized by their removal.

Analyses for the remaining USFS regions should start by adjusting dollar cost values to a common base year using an index such as the wholesale price index. This will allow the use of contracts awarded in fiscal years other than 1976 and 1977, increasing the data base by at least 350 cases. Item 14 and possibly Item 13 will no longer be needed in the analysis. A frequency distribution of all variables should follow giving some indication as to the possible stratification points in the population. Each point identified may then be tested using a t or F test to determine if there is a significant difference in the means. Upon completion of this phase of testing in all regions, it may be possible to group across region boundaries. For example, if no significant difference in mean per acre cost for site preparation in the lodgepole pine forest exists, then forest type may be an appropriate stratification criteria. This may result in substantially more available observations from which better estimates may result. A more thorough examination of stratification points than was made in this study may also eliminate the need for control (dummy) variables in many situations. If, in fact, this is the result, then adequate numbers of observations for the relatively few continuous variables will be a must.

Cost effective evaluations of the different methods would benefit when a large enough number of observations exist to develop equations

specific to each method. A major drawback of the models presented in this study is their inability, in general, to adequately represent all the possible methods. That is, the low number of observations for many methods required the use of dummies, since individual equations for each method would be based on too few cases to make any statistically sound inferences. Consequently, the approach usually identifies only the most expensive (time consuming), or the least expensive, or some combination of both methods. The user is then left with the implication that those methods not represented all basically cost the same amount.

In summary, it should be apparent that the models developed in this study are based on the most basic stratification i.e., the USFS Region. Analysis conducted at this level represent the preliminary examinations to determine the feasibility of developing site-specific silvicultural cost models. Results show the tremendous improvements in predictive accuracy possible as compared to the current method; cost averages. In addition, influential factors were identified and recommendations concerning their collection were made. Of particular interest, was the discovery of problem areas and the development of a methodology that simultaneously addressed the study objectives, while dealing with the problems. Insights gleaned from this experience should be especially useful to future analysis.

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APPENDIX

Table 1. Key to New Variable Designations

*Dummy variable names shown are the ones appropriate for USDA Forest Service Region 6

Original Item Designation	New Variable(s) for New Item Designations
Item 1. (Contract)	Item 1. (Contract)
Item 2. (Region)	Item 2. (Region)
Item 3. (Sample Number)	Item 3. (Number of reporting form for multiple area representation.)
	Items 4-7 (Blank)
	Item 8. (Blank on "9" indicating a single reporting form representing all multiple areas.)
	Item 9. (Card type 1)
Item 4. (Forest)	Item 10. (Recoded with 0, 1 west to represent forests located on the east side of Cascade range of West Side respectively.) Dummy variable designation for:* USFS2 - Deschutes National Forest USFS2 - Fremont National Forest USFS3 - Mt. Baker/Snoqualmie National For. USFS4 - Mt. Hood/Snoqualmie National For USFS5 - Ochoco/ Snoqualmie National For. USFS6 - Okanogan/Snoqualmie National For. USFS7 - Omympic/Snoqualmie National For. USFS8 - Rogue River/Snoqualmie National For. USFS9 - Siskigou/Snoqualmie National For. USFS10 - Siuslaw/Snoqualmie National For. USFS11 - Umatilla/Snoqualmie National For. USFS12 - Umqua/Snoqualmie National For. USFS13 - Wallawa - Whittman National For. USFS14 - Wenatchee National For. USFS15 - Winema National For. USFS16 - Colvile National For. Reference - Gifford Pinchot National For.
Item 5 (District)	Item 11. (District)
Item 6 (State)	Item 12. (State)

Table (continued)

Item 7. (Contract Date)	Item 13. (Month contract was awarded. Recoded with o, 1 to reflect first three quarters & last quarter in the fiscal year, respectively.)
	Item 14. (4 year contract awarded. Recoded with o, 1 to account for inflation between fiscal years, 1976 & 1977, respectively.)
Item 8. (Survey Date)	Item 15. (Survey Date)
Item 9. (Award Value)	Item 16. (Award Value)
Item 9a. (Hourly Rate)	Item 17. (Hourly Rate)
Item 10. (Cost)	Item 18. (Cost)
Item 11. (Bids)	Item 19. (Bids)
Item 12a. (Equipment)	Item 20. (Equipment)
Item 12b. (Employees)	Item 21. (Employees)
Item 12c. (Percentage)	Item 22. (Percentage)
Item 12d (Years)	Item 23. (Years)
Item 13a (Success)	Item 24. Dummy variable designation for:
	Degree 1- All terms of contract completed with time extension.
	Degree 2- Less than all terms of contract completed within specified time period.
	Degree 3- Less than all terms of contract completed with time extension.
	Reference:
Item 13b. (Quality)	Item 25. Dummy variable designation for:
	Qual 1 Good
	Qual 2 Fair-acceptable
	Reference Excellent
Item 14. (Work Began)	Item 26 (Month work began)
	Item 27. (Year work began)
Item 15. (Work Ended)	Item 28. (Month Work Ended)
	Item 29. (Year Work Ended)

Table (continued)

	Item 30. (Contract)
	Item 31. (Region)
	Item 32. (Number of reporting form for multiple area representation.)
	Items 33 - 36 (Blank)
	Item 37. (Blank or "9" indicating a single reporting form representing all multiple areas.)
	Item 38. (Card type 2.)
Item 16. (Labor)	Item 39. (Labor)
Item 17. (Man-hours)	Item 40. (Man-hours)
Item 18. (Equipment)	Items 41-45 (Equipment- allowing for 5 multiple entries.) Dummy variable designation for: Equip. 1 - Non-powered hand tools Equip. 2 - Powered hand tools Equip. 3 - Small farm type tractor Equip. 4 - Rubber-tired skidder type tractor Equip. 5 - Small heavy machinery (D4, 5, & 6 equivalents) Equip. 6 - Large heavy machinery (D7 & 8 equivalents) Equip. 7 - Helicopter Equip. 8 - Fixed wing aircraft Reference - Motorized vehicles
Item 19. (Equipment Hours)	Item 46. (Equipment Hours)
Item 20. (F.S. Man-hours)	Item 47. (F. S. Man-hours)
Item 21. (F. S. Grade)	Item 48. (F.S. Grade)
Item 22 (F.S. Cost)	Item 49. (F. S. Cost)
Item 23. (F. S. Material)	Items 50-56 (F.S. Material-allowing for 7 multiple entries.)

Table (continued)

		Dummy variable designation for:
		FSMAT1 - Nothing provided
		FSMAT2 - Fuel and lubrication (for machinery, chain-saws, etc.)
		FSMAT3 - Machinery (includes aircraft)
		FSMAT4 - Hand tools (powered and non-powered)
		FSMAT5 - Seedlings
		FSMAT6 - Seed
		FSMAT7 - Chemicals (herbicides, pesticides, fertilizer, etc.)
		FSMAT8 - Plantin g material (vermiculite, burlap, etc.)
		Reference - Slash paper
Item 24a. (Practice)		Item 57. (Practice A)
(Activity)		Item 58. (Activity A)
(Method)		Item 59. (Method A)
		Dummy variable designation for:*
	Site Preparation	MET 11 - Tractor and scalper
		MET 14 - Complete with bulldozer and blade
		MET 17 - Bulldozer and discs
		MET 18 - Whip felling
		MET 110 - Scarification
		MET 112 - Windrowing
		Reference - Strip with bulldozer and blade
	Reforestation	MET 119 - Hand
		MET 121 - Auger
		MET 122 - Auger & Hand
		Reference - Machine
(Method)		Item 60. (Method A2)
Item 24b. (Practice)		Item 61. (Practice B)
(Activity)		Item 62. (Activity B)
(Method)		Item 63. (Method B)
(Method)		Item 64. (Method B2)

Table (continued)

	Item 65. (Contract
	Item 66. (Region)
	Item 67. (Number of reporting form for multiple area representation.)
	Items 68 - 71. (Blank)
	Item 72. (Blank or "9" indicating a single reporting form representing all multiple areas)
	Item 73. (Card type 3.)
Item 25a. (Number)	Item 74. (Number)
Item 25b (Bid Values)	Item 75. (Bid Values)
Item 25c. (Distance)	Item 76. (Distance)
Item 26. (Acres)	Item 77. (Acres)
	ACSQU - Acres squared
	ARECIP - The reciprical of acres
	A2RECIP - The reciprical of acres squared
Item 27a. (Minutes	Item 78. (Minutes)
Item 27b. (Miles)	Item 79. (Miles)
Item 27c (Miles)	Item 80. (Miles)
Item 28. (Season)	Items 81-84 (Season-allowing for 4 multiple entries).
	Dummy variable designation for:
	SEA1 - Dec. - Feb. SEA2 - Mar. - May SEA3 - Jun. - Aug.
	Reference - Sep. - Nov.
Item 29a. (Seedlings)	Item 85. (Seedlings)
Item 29b. (Months)	Item 86. (Months)

Table (continued)

Item 29c. (Species)	Item 87. Dummy variable designation for:* SPEC1 - Douglas-fir SPEC2 - Ponderosa pine SPEC3 - Lodgepole pine SPEC4 - True firs SPEC5 - Sugar pine Reference - Engelmann spruce
Item 30. (Marked)	Item 88. (Marked)
Item 31a. (Length)	Item 89. (Length)
Item 31b. (Piling)	Item 90. (Piling)
Item 32. (Slope)	Item 91. (Slope) Dummy variable designation for: SLOP1 - Level slopes less than 8% SLOP2 - Rolling slopes 9-15% SLOP3 - Moderately steep Slopes 16-30% Reference - Steep slopes greater than 30
Item 33. (Elevation)	Item 92. (Elevation)
Item 34a. (Obstacle)	Items 93-94. (Obstacle A & B allowing for 2 multiple entries.) Dummy variable designation for: OBS1 - no impediment OBS2 - Hard compacted soils OBS3 - Streams and/or gullies OBS4 - Large rocks and/or stumps OBS5 - Dense brush OBS6 - Residual timber OBS7 - Wet bog areas OBS8 - Fragile soils or terrain OBS9 - Slope OBS10 - Down material OBS11 - Elevation OBS12 - Inclement weather OBS13 - Grass Reference - Other (Not specified)
Item 34b. (Percentage)	Item 95. (Percentage)
Item 34c. (Rating)	Item 96. (Rating)

Table (continued)

Item 35. (Forest Type)	Item 97. (Forest Type) Dummy variable designation for:* FTYPE 11 - Douglas-fir FTYPE 12 - Ponderosa pine FTYPE 14 - Fir-spruce Reference - Lodgepole pine
	Item 98. (Contract)
	Item 99. (Region)
	Item 100. (Number of reporting form for multiple area representation.)
	Items 101-104 (Blank)
	Item 105. (Blank or "9" indicating a single reporting form representing all multiple areas.)
	Item 106. (Card type 4.)
Item 36. (BA/A Before)	Item 107. - (BA/A Before)
Item 37. (BA/A Treated)	Item 108. (BA/A Treated)
Item 38. (Trees Treated)	Item 109. (Trees Treated)
Item 39. (DBH)	Item 110. (DBH)
Item 40. (Vegetative Cover)	Items 111-113. (Vegetative cover A, B. & C. - allowing for 3 multiple entries) Dummy variable designation for: VEG1 - Grass, light sod VEG2 - Grass, medium sod VEG3 - Grass, heavy sod VEG4 - Saplings and Brush, 0-4" dbh,light density VEG5 - Saplings and Brush, 0-4" dbh, medium density VEG6 - Saplings and Brush, 004: dbh, heavy density VEG7 - Poletimber, 4-10" dbh, light density VEG8 - Poletimber, 4-10" dbh, medium density VEG9 - Poletimber, 4-10" dbh, heavy density VEG10 - 10" and larger dbh material, light density VEG11 - 10" and larger dbh material, medium density

Table (continued)

Item 41. (Days on Job)	Item 114. (Days on Job)
	Item 115. (Blank)
	Item 116. (Award per acre)
	Item 117. (Cost per acre)
	Item 118. (Man-hours per acre)
	Item 119. (Equipment-hours per acre)
	Item 120 (USFS Man-hours per acre)
	Item 121 (USFS Cost per acre)
	Item 122. (Fire line per acre)
	Item 123. (Days per acre)

SURVEY OF SILVICULTURAL SERVICE CONTRACTS

This questionnaire is designed to collect data needed for the development of cost prediction equations for silvicultural practices. Care and accuracy should be maintained while completing this form since the reliability of the final equations is directly related to the quality of the data received. Following the receipt of the reporting forms, regression analysis will be employed to identify those factors which appear to influence the cost of a particular job in a given locale. If you, as the respondent, feel the questionnaire has neglected to consider an important factor or some aspect of the contracting process which does have a significant impact on the cost of operations in your area, please record your comments on the back of the reporting form under the "Remarks" heading.

INSTRUCTIONS FOR COMPLETING FORM

1. Report on all silvicultural service contracts awarded and completed in FY 1976 and 1977, including the transition quarter of 1976, whether negotiated or advertised, regardless of contract funding source. Only report contracts pertaining to the establishment and/or maintenance of forested areas. Also report contracts which address inventory procedures and management plan prescriptions. Do not report projects concerned with engineering, harvesting, or animal control other than for direct or natural seeding. At least one reporting form must be completed for each contract.

2. Multiple Areas. If a contract covers more than one non-contiguous area, categorize the individual areas on the basis of common bid values and uniform plant communities (or forest type), stand and site characteristics. Choose one non-contiguous area within each category for which enough information is available to complete an entire reporting form. The reporting form for that area will be treated as representative of that category. Prorate all reported values specific to that one area representing the category under consideration. For example, if three different bid values were awarded for a number of non-contiguous areas, at least three separate reporting forms must be completed, each reflecting values specific to the area chosen to represent each bid value category. Similarily, if two different plant communities (or stand and site characteristics) occur within one bid value category, at least two additional reporting forms must be completed, and so on until all categories have been accounted for.

3. Do not report contracts:(a) whose terms or values are under appeal, or (b) in which the value of salvaged timber affected the amount bid on the contract.

4. The Stand Description Inventory (Stage II Survey) for the tract in which the contract was awarded and, if available, the cost estimate appraisal (or some other source of direct cost estimate) prepared by the contracting officer, contain most of the information sought by this survey. Enter the best estimate if the requested data is not available in office records.

5. Report all figures to the nearest whole dollar, inch, mile, acre, or hour. Do not place decimals, commas, hyphens, dollar signs or marks other than numbers on the reporting form. Item 9a. is the only place a decimal is allowed.

6. If a written answer to a question conveys a more complete explanation or a code signifying "other" is entered, record the information on the back of the reporting form preceded by the item number.

7. Enter N A if a question is not applicable to the particular job under contract.

8. If available, a xerox copy of the cost estimate appraisal, prepared by the contracting officer for the contract under consideration, should be returned attached to the reporting form.

9. Should questions arise concerning the completion of the reporting form, or additional forms needed, leave message at FTS #323-1265.

INSTRUCTIONS FOR COMPLETING FORM

Contract Identification

Item 1. Contract. Record the contract designation number.

Item 2. Region. Record the standard U.S.F.S. Region number in which the contract was awarded.

Item 3. Sample. Leave this space blank.

Item 4. Forest. Record the standard National Forest code number in which the contract was awarded.

Item 5. District. Enter the standard Ranger District code number in which the contract was awarded.

Item 6. State. Enter the standard state code number in which the contract was awarded.

Item 7. Contract Date. Record the month and year in which the contract was awarded. For example, a date of March, 1977 should be recorded as 0 3 7 7.

Item 8. Survey Date. Record the month and year the Stand Description Inventory (Stage II survey) used to complete this form was compiled.

Contract Information

Item 9. Award Value. Enter the total dollar amount bid by the contractor, i.e. the total award value. If bids were submitted on a per-acre basis, convert the values to represent the entire job by multiplying the per-acre bid by the total number of acres to be treated and record that value. Prorate this figure for multiple area contracts. (a) If bids were submitted on an hourly basis enter N A for Award Value and place the hourly rate in the next space (Hourly Rate) on reporting form. A decimal may be used in this case only.

Item 10. Cost. Enter the total dollar amount finally paid to the contractor at the completion of the project.

Item 11. Bids. Record the number of bids received on this contract. If negotiated, enter 0.

Item 12. Contractor Status. Record the following requested information which indicates the size, competence, and experience of the contracting enterprise being dealt with as follows: (a) An estimate of the total number of individual pieces of equipment owned and operated by the contractor. (b) The total number of employees working for the contractor. (c) A percentage estimate of the contractor's time spent performing silvicultural tasks. (d) The number of years contractor has been in the business of performing silvicultural operations.

Item 13. Job Performance. (a) Enter the code which describes the success of the contracted operation as follows:

Code	Degree of success
1	All terms of contract completed within specified time allotment.
2	All terms of contract completed with time extension.
3	Less than all terms of contract completed within specified time period.
4	Less than all terms of contract completed with time extension.

(b) Rate the quality of the completed work as follows:

Code	Quality
1	Excellent
2	Good
3	Fair-acceptable
4	Poor-not acceptable, work will have to be redone

Item 14. Work Began. Record the month and year field work actually started on contracted project. For example, a date of February, 1976 should be recorded as 0 2 7 6.

Item 15. Work Ended. Record the month and year field work was completed on contracted project.

Labor and Equipment Requirements

Item 16. Labor. Record the total number of non-Forest Service personnel directly involved with the field operation.

Item 17. Man-hours. Enter an estimate of the total number of non-F.S. man-hours required to complete the operation.

Item 18. Equipment. Enter code(s) for type of equipment used to complete the operation as follows:

Code	Equipment type
1	Non-powered hand tools
2	Powered hand tools
3	Small farm type tractor
4	Rubber-tired skidder type tractor
5	Small heavy machinery (D4, 5, & 6 equivalents)
6	Large heavy machinery (D7 & 8 equivalents)
7	Helicopter
8	Fixed wing aircraft
9	Other (specify)

Item 19. Equipment hours. Enter an estimate of the total number of equipment hours required to complete the operation.

Forest Service Contribution

Item 20. F.S. Man-hours. Record the total number of Forest Service man-hours required in the field for direct preparation, supervision, and inspections. Do not include SO or RO time.

Item 21. F.S. Grade. Record the average GS grade of Forest Service personnel directly involved in the field operation.

Item 22. F.S. Cost. Record the total cost (dollars) of materials and/or equipment provided by the Forest Service.

Item 23. F.S. Materials. Enter 1-digit code(s) for Forest Service provided material(s). If more than one material provided, list in order of importance.

Code	Material
1	Nothing provided
2	Fuel and lubrication (for machinery, chain-saws, etc.)
3	Machinery (includes aircraft)
4	Hand tools (powered and non-powered)
5	Seedlings
6	Seed
7	Chemicals (herbicides, pesticides, fertilizer, etc.)
8	Other (specify)

Operation Characteristics

Item 24. Job Specifications. The operation performed is described by the general practice, activity, and method(s) employed to complete that operation. Record codes for (a) the general practice specified by the contract, (b) the activity accomplished, and (c) the method(s) employed to complete that activity. Methods are grouped under activities to aid in locating methods normally employed, however, any reasonable method(s) may be reported regardless of the activity under which it is listed. Up to two methods can be reported.

Note: If more than one operation was accomplished, enter the codes corresponding with the more costly operation under Item 24(a) and the codes corresponding to the second most costly operation under Item 24(b).

For example, the contract specifies site preparation to be completed using a dozer terracing procedure in conjunction with burning. This operation is to be followed by machine planting of the entire treated area. The reporting form should be completed as follows:

JOB SPECIFICATIONS			
Item 24a.			
Practice	Activity	Method(s)	
1 0 0	1 2 1	1 1 1	1 1 6
56-58	59-61	62-64	65-67

JOB SPECIFICATIONS			
Item 24b.			
Prac-	Activity	Method(s)	
2 0 0	2 2 0	2 0 1	
68-70	71-73	74-76	77-79

General Practice Code	Activity Code	Method Code	General Practice / Activity / Method
100			Site Preparation
	120		For Seeding
	121		For Planting
	122		For Natural Regeneration
		101	Tractor and scalper
		102	Strip with bulldozer and blade
		103	Strip with tractor and chopper
		104	Complete with bulldozer and blade
		105	Complete with tractor and chopper
		106	Tractor and plow
		107	Bulldozer and discs
		108	Bulldozer and cable
		109	Whip felling
		110	Combination and cable
		111	Dozer terracing
		112	Scarification
		113	Furrowing
		114	Raking
		115	Windrowing
		116	Burning
		117	Mobile chipper
		118	Crushing - Dozer without blade
		---	(Any method listed under Timber Stand Improvement)
		199	Other (specify)
200			Reforestation
	220		Full Planting
	221		Fill-in Planting
	222		Backlog Area Planting
		201	Machine
		202	Hand
		203	Machine and hand
		204	Auger
		205	Auger and hand
		206	Auger and machine
		299	Other (specify)
	230		Full Seeding
	231		Fill-in Seeding
	232		Backlog Area Seeding
		207	Helicopter
		208	Fixed wing aircraft
		209	Hand broadcast
		210	Hand spot
		211	Tractor drawn machine
		299	Other (specify)
	240		Natural Regeneration with Site Preparation
	241		Natural Regeneration without Site Preparation
	242		Natural Regeneration Backlog Area with Site Preparation
	243		Natural Regeneration Backlog Area without Site Preparation
	250		Animal Control (for direct or natural seeding)
		212	Helicopter
		213	Fixed wing aircraft
		214	Hand
		299	Other (specify)
300			Timber Stand Improvement
	330		Control of Understory Vegetation
	331		Cleaning
	332		Release, Individual Tree
	333		Release, Area
		301	Helicopter chemical spray
		302	Fixed wing chemical spray
		303	Mobile spray unit
		304	Mobile spray unit with hand spray
		305	Backpack chemical spray
		306	Injector
		307	Girdling or frilling with spray
		308	Girdling
		309	Felling
		310	Prescribed burning
		399	Other (specify)

General Practice Code	Activity Code	Method Code	General Practice / Activity / Method
300			Timber Stand Improvement
	340		Precommercial Thinning
		311	Power saw
		312	Bulldozer with blade
		313	Tractor with chopper
		314	Hand pulling
		—	(Any method listed under Release...)
		399	Other (specify)
	350		Pruning
		315	Power saw
		316	Non-powered hand saw
		399	Other (specify)
	360		Fertilization
		317	Hand
		318	Machine
		319	Helicopter
		320	Fixed wing aircraft
		399	Other (specify)
400			Protection Activities
	420		Fire Prevention
		401	Fire line construction
		402	Fuel reduction by prescribed fire
		403	Fuels reduction
		404	Fire risk fuels reduction
		405	Understory vegetation density fuels reduction
		499	Other (specify)
	430		Slash Disposal
		406	Removal or pulling back
		407	Chipping in place
		408	Lopping and scattering
		409	Hand piling for burning
		410	Machine piling for burning
		411	Slashing for burning
		412	Burning in place
		413	Crushing by tractor and tomahawk
		499	Other (specify)
	440		Pest Control
		413	Stump spraying with chemicals
		414	Disease host eradication by hand
		415	Disease host eradication by prescribed fire
		416	Disease host eradicated by chemical
		417	Disease or pathogen control with prescribed fire
		418	Eradication of disease or insect infested trees
		—	(Any method listed under Timber Stand Improvement)
		499	Other (specify)
500			Administration
	520		Timber Management Planning and Inventories
		501	Photography and mapping for timber resource inventory and timber management planning
		502	Timber resource general inventory data gathering and permanent plot maintenance
		503	Inventory field data analysis
		504	Inventory data compilation
		505	Timber management plan preparation and annual maintenance of the plan
		599	Other (specify)
	530		Compartment Examination and Prescription (Stand)
		506	Photography and mapping for compartment and stand examination
		507	Stand field data gathering
		508	Stand data compilation
		509	Stocking survey
		510	Plantation survival survey
		511	PSI survey
		512	Fuels survey
		513	Insect and disease survey
		599	Other (specify)
600			Other Treatments (specify method)

Item 25. Multiple Areas. (a) Record the number of non-contiguous areas represented by this contract being reported. Enter a 1 if only one contiguous area was covered by the contract and enter N A for the next two answers on reporting form. (b) Record the total number of different bid values awarded for different non-contiguous areas under the original contract. (c) Record the average distance separating (miles) each of the non-contiguous areas represented by this reporting form.

Item 26. Acres. Record the total number of acres treated in the area covered by contract or representative area.

Item 27. Travel Time. Enter an estimate of the average one-way travel time to project from contractor's base of operation in (a) minutes, (b) miles, and (c) miles to tract from all-weather roads.

Item 28. Season. Enter the code(s) for the season the majority of the work took place. Enter the appropriate sequence of codes if the project spanned over one season.

Code	Season
1	Dec. - Feb.
2	Mar. - May
3	Jun. - Aug.
4	Sep. - Nov.

Item 29. Planting. If practice involved planting or seeding, (a) record the number of seedlings or seed planted per acre, (b) record the number of months between date site preparation completed and date of planting or seeding, (enter a code of N A if no site preparation performed) (c) list species planted or seeded on reverse side of reporting form.

Item 30. Marked. Enter a code of 1 if treated stems were marked for identification prior to treatment or if only particular species were treated. Enter a code of 0 if a systematic means of treatment such as strips were employed where no marking was involved.

Item 31. Fire Line. If fire lines were constructed (a) record the total number of feet constructed (b) enter a 1 if piling was also performed, otherwise enter 0.

Site Characteristics

Item 32. Slope. Record slope code that best typifies the majority of the treated area as follows:

Code	Slope class	
1	Level	slopes less than 8%
2	Rolling	slopes 9-15%
3	Moderately steep	slopes 16-30%
4	Steep	slopes greater than 30%

Item 33. Elevation. Record the average elevation above sea level of the treated area.

Item 34. Operability. (a) Enter the code(s) which describes obstacles hindering the movement of equipment or manpower in the process of the prescribed treatment. List codes which apply beginning with that factor having the greatest impact on operability (b) Enter a percentage estimate of the total area effected by obstacle

Code	Obstacle	Code	Obstacle
01	No impediment	08	Fragile soils or terrain
02	Hard compacted soils	09	Slope
03	Streams and/or gullies	10	Down material
04	Large rocks and/or stumps	11	Elevation
05	Dense brush	12	Inclement weather
06	Residual timber	13	Other (specify)
07	Wet bog areas		

(c) Rate operability as follows:

Code	Rating
1	Did not appreciable interfere with work effort
2	Limited choice of equipment used
3	Caused intermittent curtailments of work progress
4	Severly limited progress throughout course of operation

Stand Characteristics

Item 35. Forest Type. Record the code representing the forest type of the project area, prior to treatment.

Code	Eastern Type
100	Red-white - jack pine
110	Spruce-fir
120	Longleaf - slash pine
130	Loblolly - shortleaf pine
140	Oak - pine
150	Oak - hickory
160	Oak - gum - cypress
170	Elm - ash - cottonwood
180	Maple - beech - birch
190	Aspen - birch

Code	Western Type
200	Douglas-fir
210	Ponderosa pine
220	Western white pine
230	Fir - spruce
240	Hemlock - Sitka spruce
250	Larch
260	Lodgepole pine
270	Redwood
280	Hardwoods
290	Non-commercial types (examples are: juniper, pinyon pine and chapparal)

Item 36. BA/A Before. Record total basal area per acre prior to treatment.

Item 37. BA/A Treated. Record total basal area per acre treated or removed.

Item 38. Trees Treated. Record the number of stems treated or removed per acre.

Item 39. DBH. Record the average dbh (nearest inch) of all treated or removed stems.

Item 40. Vegetative Cover. Enter the code(s) which best describes the size and amount of ground cover occuring on the treatment area as follows:

Code	Ground Cover
01	Grass, light sod
02	Grass, medium sod
03	Grass, heavy sod
04	Saplings and Brush, 0-4" dbh, light density
05	Saplings and Brush, 0-4" dbh, medium density
06	Saplings and Brush, 0-4" dbh, heavy density
07	Poletimber, 4-10" dbh, light density
08	Poletimber, 4-10" dbh, medium density
09	Poletimber, 4010" dbh, heavy density
10	10" and larger dbh material, light density
11	10" and larger dbh material, medium density
12	10" and larger dbh material, heavy density

Note: stand density is an expression of the percentage of growing space occupied; light - less than 40% crown closure, medium - 41-70% crown closure, heavy-greater than 70% crown closure.

Item 41. Days on Job. Record the total number of days of work required to complete the operation.

Item 42. Remarks. Please report any items which make the contract award value unusually high or low or other peculiarities which might make the evaluation of this contract more meaningful. Record this information under the "Remarks" heading on the back of the reporting form.

☆ GPO 1978 778-551

Item 1. Contract	Item 2. Region	Item 3. Sample Number
1-8	9-10	11-16

SURVEY OF SILVICULTURAL SERVICE CONTRACTS

REPORTING FORM

Prepared by:____________________

Date:__________ FTS #:__________

Card Type	CONTRACT IDENTIFICATION					CONTRACT INFORMATION							
	Item 4. Forest	Item 5. District	Item 6. State	Item 7. Contract Date	Item 8. Survey Date	Item 9. Award Value	Item 9a. Hourly Rate	Item 10. Cost	Item 11. Bids	Item 12. Contractor Status			
										(a) Equipment	(b) Employees	(c) Percentage	(d) Years
1													
17	18-20	21-22	23-24	25-28	29-32	33-41	42-47	48-56	57-58	59-61	62-64	65-67	68-69

CONTRACT INFORMATION			
Item 13. Job Performance		Item 14. Work Began	Item 15. Work Ended
(a) Success	(b) Quality		
70	71	72-75	76-79

Card Type	LABOR AND EQUIPMENT REQUIREMENTS				FOREST SERVICE CONTRIBUTION				JOB SPECIFICATIONS			
	Item 16. Labor	Item 17. Man-hours	Item 18. Equipment	Item 19. Equipment Hours	Item 20. F.S. Man-hours	Item 21. F.S. Grade	Item 22. F.S. Cost	Item 23. F.S. Material	Item 24a.			
									Prac-tice	Activ-ity	Method(s)	
2												
17	18-20	21-24	25-29	30-33	34-37	38-39	40-48	49-55	56-58	59-61	62-64	65-67

JOB SPECIFICATIONS				
Item 24b.				
Prac-tice	Activ-ity	Method(s)		
68-70	71-73	74-76	77-79	

Card Type	OPERATION CHARACTERISTICS										
	Item 25. Multiple Areas			Item 26. Acres	Item 27. Travel Time			Item 28. Season	Item 29. Planting		
	(a) Number	(b) Bid Values	(c) Distance		(a) Minutes	(b) Miles	(c) Miles		(a) Seedlings	(b) Months	(c) Species
3											
17	18-19	20-21	22-24	25-30	31-33	34-36	37-39	40-43	44-47	48-49	50-52

OPERATION CHARACTERISTICS			SITE CHARACTERISTICS					
Item 30. Marked	Item 31. Fire Line		Item 32. Slope	Item 33. Elevation	Item 34. Operability			Item 35. Forest Type
	(a) Length	(b) Piling			(a) Obstacle	(b) Percentage	(c) Rating	
53	54-56	57	58	59-63	64-67	68-70	71	72-74

Card Type	STAND CHARACTERISTICS						
	Item 36. BA/A Before	Item 37. BA/A Treated	Item 38. Trees Treated	Item 39. DBH	Item 40. Vegetative Cover	Item 41. Days on Job	
4							
17	18-21	22-25	26-29	30-31	32-37	38-41	

Please record comments on the back of reporting form.